THE JOURNAL OF ENGINEERING EDUCATION

VOLUME 38 NUMBER 1

Contents for September, 1947

THE AMERICAN SOCIETY FOR ENGINEERING EDUCATI(
OFFICERS 1947–48

President

Charles E. MacQuigg, The Ohio State University, Columbus 10, Ohi(

Vice President, 2 years

(In charge of general and regional activities)

B. J. Robertson, University of Minnesota, Minneapolis, Minn.

Vice President, 1 year

(In charge of instructional division activities)

C. J. Freund, University of Detroit, Detroit, Mich.

Vice President, 2 years

(Engineering College Administrative Council)

S. S. Steinberg, University of Maryland, College Park, Md.

Vice President, 1 year

(Engineering College Research Council)

F. M. Dawson, State University of Iowa, Iowa City, Iowa

Secretary

F. L. Bishop, University of Pittsburgh, Pittsburgh 13, Pa.

Treasurer

J. S. Thompson, McGraw-Hill Book Co., New York 18, N. Y.

Assistant Secretary

Nell McKenry, University of Pittsburgh, Pittsburgh 13, Pa.

Headquarters

University of Pittsburgh, Pittsburgh 13, Pa

56th Annual Meeting

Austin, Texas, June 14-18, 1948

Host

University of Texas

McGRAW-HILL • *Notable New Editions*

Radio Engineering. ***New 3rd edition***

By Frederick E. Terman, Stanford University. McGraw-Hill Series in Electrical and Electronic Engineering. Ready in fall

A revised, up-to-date edition of this comprehensive treatment covering all phases of radio communication, written from the viewpoint of the engineer who is interested not only in qualitative descriptions of radio phenomena, but also in making quantitative analyses for facilitating design and research.

Principles of Industrial Organization. ***New 6th edition***

By Dexter S. Kimball, Cornell University, and Dexter S. Kimball, Jr., Bendix-Westinghouse Automotive Airbrake Company. McGraw-Hill Industrial Organization and Management Series. Ready in September

Offers a lucid treatment of the internal organization and procedures of industrial enterprises, and considers industrialism from the broader points of view of economic organization in general. Much new material has been added on subjects of present-day importance.

Elementary Engineering Thermodynamics. ***New 3rd edition***

By Vincent W. Young, Oklahoma A. & M. College, and Gilbert A. Young, Purdue University. Ready in September

The strong features of this text are (1) its coverage, which is unusually broad, in view of its design as the basis of a short, introductory course in thermodynamics, and (2) the simple method of treatment. The new edition offers revised discussions of flow energy, Joule's law, entropy, etc.

Engineering Drawing. ***New 7th edition***

By the late T. E. French; revised by C. J. Vierck, The Ohio State University. With the assistance of Members of the Department of Engineering Drawing, The Ohio State University. 702 pages, $3.75

The new 7th edition of this classic textbook has been completely and carefully revised, and new material, problems, and illustrations have been added to bring it abreast of the latest advances in engineering and pedagogy. New editions of French and McCully's **Engineering Drawing Sheets,** and Levens and Edstrom's **Problems in Engineering Drawing** will be available. Also available for fall classes will be a series of TEXT-FILMS — sound motion pictures and silent filmstrips—supplementing selected parts of French's *Engineering Drawing.*

Principles and Practice of Electrical Engineering. ***New 6th edition***

By the late Alexander Gray, Cornell University. Revised by G. A. Wallace, McGill University. Ready in September

Emphasizes fundamental principles. New topics include the emplidyne, ignitron, fluorescent lamps, tetrodes, push-pull amplifier, electronic timer, and stroboscope.

•

Soil Mechanics. ***New 2nd edition***

By D. P. Krynine, Yale University. $5.50

Deals with the principles used in the design, construction, and maintenance of foundations of structures, and of structures themselves, made of earth materials. All material has been brought up to date.

McGRAW-HILL

Important New Texts • McGRAW-HILL

Direct-current Machinery

By G. C. Blalock, Purdue University. 383 pages, $3.75

A concise but balanced picture of basic and specialized d.c. machines and their controls. Free use has ben made of practical illustrative examples, problems, and illustrations, in order to give the student a real conception of the practical significance of the theory studied.

Electronic Circuits and Tubes

By Members of the War Training Staff, Cruft Laboratory, Harvard University. 954 pages, $7.50

Together with its companion volume *Transmission Lines, Antennas, and Wave Guides*, this book has developed from a special wartime training course given at Cruft Laboratory, preparing officers of the Army and Navy for work in radar and its applications. The authors present the basic theory of electronic tubes and electric circuits employed in conjunction with electronic tubes.

Production with Safety

By A. L. Dickie, Supervising Safety Engineer. 254 pages, $2.50

Presents accident prevention as a profitable plant investment, and shows how control of accidents to workers, machines, and materials will reduce costs and increase production efficiency. Thirteen complete safety talks are included and serve as a basic course in accident prevention.

Industrial Applications of Infrared

By J. D. Hall, Westinghouse Electric Company. Ready in fall

Gives essential data necessary for a clearer understanding of the place infrared radiation occupies in the field of heat transfer. Includes details on infrared lamp operating characteristics, description of available infrared equipment, outline of simple test procedure, etc.

Very High-frequency Techniques

Compiled by the Staff of the Radio Research Laboratory, Harvard University. OSRD–NDRC. Two volumes (not sold separately). 1045 pages, $14.00

Presents those techniques, at frequencies above about 100 mc, that are of general interest and value. Gives a comprehensive treatment of antennas, direction finding systems, generation of continuous wave power, and reception of signals.

Mathematical Theory of Rocket Flight

By J. B. Rosser, Cornell University, R. R. Newton, Bell Telephone Laboratories, Murray Hill, N. J., and G. L. Gross, Grumman Aircraft Engineering Corporation. OSRD–NDRC. 304 pages, $4.50

Up to date, comprehensive, and definitive, this book constitutes the official report to the OSRD on the work done during the war at the Allegany Ballistics Laboratory in the development of the rocket. The presentation is reasonably nontechnical.

Control Charts. An Introduction to Statistical Quality Control.

By E. S. Smith, University of Cincinnati. McGraw-Hill Industrial Organization and Management Series. 184 pages, $3.00

A text on the purposes, construction, and interpretation of the charts of statistical quality control, emphasizing practical applications rather than the development of mathematical formulas. There is a detailed but nonmathematical treatment of frequency curves and their value in interpreting statistical data.

Send for copies on approval

McGRAW-HILL BOOK COMPANY, Inc.

330 West 42nd Street, New York 18, N. Y.

NEW WILEY BOOKS

INDUSTRIAL HEALTH ENGINEERING, by A. D. Brandt.

A concise and practical treatment of the science of maintaining the worker's environment in a condition conducive to good health, and thus keeping all harmful environmental exposures away from him.

November. Approx. 395 pages Prob. price $6 00.

ARCHITECTURAL CONSTRUCTION, by Theodore Crane.

Aids the designer in choosing the appropriate structural system and secondary structural elements on the basis of geographical location, site conditions, type of occupancy, equipment, and architectural design.

October Approx. 410 pages. Prob price $6 00.

HEAT, by A. G. Worthing and David Halliday.

Offers a clear and thorough study of heat, written with emphasis on the experimental rather than the theoretical viewpoint Terms, symbols, and units have been carefully selected and definitions precisely phrased and consistently used.

December. Approx. 610 pages Prob. price $6 00.

PRACTICAL JOB EVALUATION, by P. W. Jones.

Presents the practical aspects of job evaluation. Points out the actual problems and pitfalls in formulating and installing a uniform wage program, and gives tested means for solving and avoiding them.

January Approx. 303 pages. Prob. price $5.00.

NON-FERROUS PRODUCTION METALLURGY, by J. L. Bray.

Presents the same general plan, but features recent developments; much additional material on aluminum, copper, magnesium, nickel, and tin; the solution of practical problems; and applications of physical chemistry to metallurgical processes.

Second Edition, September. Approx. 587 pages. Prob. price $5.00.

DATA BOOK FOR CIVIL ENGINEERS, Vol. III, FIELD PRACTICE, by E. E. Seelye.

The third volume is directed to the field engineer or inspector, and furnishes him with data on all aspects of his work. The material is divided into two sections—Inspection, and Surveying.

November. Approx. 305 pages. Prob. price $6.00.

NOMOGRAPHY, by A. S. Levens.

A thorough study of the fundamentals of graphical methods which show how alignment charts can help engineers in many fields to eliminate tedious mathematical computations.

December Approx. 161 pages. Prob. price $3.00.

ELEMENTARY NUCLEAR THEORY, by H. A. Bethe.

Emphasizes the problem of nuclear forces—the central problem of nuclear physics. The material is treated from the empirical point of view and the behavior of the simplest nuclear systems is stressed.

September. 147 pages. $2 50

MAGNETIC CONTROL OF INDUSTRIAL MOTORS, by G. W. Heumann.

Explains the performance of motors, characteristics of control devices, and the function of commonly used control circuits Emphasizes considerations governing the selection of controllers for specific jobs

November Approx. 589 pages. Prob. price $7 50

VACUUM TUBE CIRCUITS, by L. B. Arguimbau.

Presents, among other topics, an excellent chapter on inverse feedback; extended treatment of frequency modulation; clear discussions of transient response of video amplifiers, pulses, and television; and many examples and problems.

January. Approx. 656 pages. Prob. price $6.00.

Other WILEY books on front cover and page 7

JOHN WILEY & SONS, INC., 440 Fourth Ave , New York 16, N. Y.

NEW WILEY BOOKS

WIND TUNNEL TESTING, by Alan Pope.

An integrated work which covers design of wind tunnels, testing procedures, and corrections to be applied to wind tunnel data.

September. 319 pages. $5.00.

INDUSTRIAL MANAGEMENT, by the late R. H. Lansburgh and W. R. Spriegel; revised by W. R. Spriegel.

This edition discusses the principles, problems, ideals, and successful methods of organization, and offers new material on maintenance and more than 125 new illustrations.

Fourth Edition, September. 656 pages. $5.00.

CORROSION HANDBOOK, edited by H. H. Uhlig.

A condensed summary of corrosion information, including a cross-section of scientific data and industrial experience. Discussion is concerned largely with corrosion protection and the behavior of metals and alloys in environments at ordinary and elevated temperatures.

January.

THEORY OF LIMIT DESIGN, by J. A. Van den Broek.

Gives a clear dissertation on the fundamental principles that constitute a basis for the theory of limit design. Emphasizes ductile stress distribution instead of elastic stress distribution.

December. Approx. 148 pages. Prob. price $3.00.

POWER SYSTEM STABILITY, Vol. I, by E. W. Kimbark.

The first of three volumes, this book stresses transient stability rather than steady-state stability. Includes elements of the stability problem and simple methods of calculation; underlying theory for more accurate calculation; means of improving system stability, including circuit breakers and protective relays.

December. Approx. 356 pages. Prob. price $7.00.

FUNDAMENTALS OF ELECTRICITY AND MAGNETISM, by L. B. Loeb.

This edition presents magnetic phenomena, followed by the electromagnetic definition of current and potential. The gaussian system of units is used consistently throughout. Some historical material has been deleted to allow for important new information.

Third Edition, September. Approx. 669 pages. Prob. price $6.00.

RAILROAD ENGINEERING, by the late W. G. Raymond, H. E. Riggs, and W. C. Sadler.

The new edition of this "classic" has been completely revised in the light of technical developments and the establishment of new regulations. The practical approach of the previous editions is retained.

Sixth Edition, October. Approx. 442 pages. Prob. price $5.00.

STEEL AND ITS HEAT TREATMENT, Vols. I & II, by D. K. Bullens, and the Metallurgical Staff of Battelle Memorial Institute.

Vol. I deals with the definitions, terminology, and fundamental concepts necessary for a discussion of heat treatment; with the principles underlying various types of heat treatment; and with evaluating the suitability of steel for heat treatment. Vol. II discusses the applications of the principles and the tools of heat treatment. Both volumes emphasize the practical approach.

Fifth Edition, January. Vol. I. Approx 496 pages. Prob. price $5.00. Vol. II. Approx. 295 pages. Prob. price $5.00

FLIGHT ENGINEERING AND CRUISE CONTROL, by H. G. Moe.

Gives a clear discussion of airplane engines, the basic principles of their construction and the techniques for their efficient operation. Covers air speed, power, altimeters, propellers and propeller efficiency, cruising techniques and flight planning.

November. Approx. 235 pages. Prob. price $4.00.

Other WILEY books on front cover and page 6

JOHN WILEY & SONS, INC., 440 Fourth Ave., New York 16, N. Y.

Charles Ellison MacQuigg, President 1947–48

Charles Ellison MacQuigg was born in Ironton, Ohio, January 19, 1885. He received the E.M. in 1909, and later the honorary degree Eng. Dr. from Clarkson College of Technology. He was civil engineer on the Santa Fe Railway, 1909–10; assistant engineer of tests, Anaconda Copper Mining Co., 1910–12; head, department of metallurgy at The Pennsylvania State College, 1912–17; engineering research and commercial development, Union Carbide and Carbon Co., 1919–37; Dean, College of Engineering, The Ohio State University since 1937; also Director Engineering Experiment Station.

Dean MacQuigg has been Lt. Colonel, Ordnance Reserve, U. S. Army; Regional Adviser ESMWT; Chairman, Ohio Water Resources Board; Member, Executive Committee, Engineering Division, Association of Land Grant Colleges and Universities; Metallurgical Advisory Committee, National Research Council with various assignments on NDRC; Ohio Farm Chemurgic Committee; Newcomen Society of England; Sigma Xi, Tau Beta Pi, AIMME, ASTM, ASM, ASME, AAAS; Fellow, Ohio Academy of Science; Recipient of the James Turner Morehead medal of the International Acetylene Association; the inventor of metallurgical patents, and author of many technical papers.

Dean MacQuigg became a member of the Society in 1937, was a member of the Council 1939–40, and Vice President 1942–43.

Lamme Award—Warren Kendall Lewis

To Warren Kendall Lewis for his great part in the development of chemical engineering in its modern quantitative aspects; for his contributions to its fundamental concepts, and to their many important applications in chemical industry; for the vision, inspiration, and sound methods imparted to his students through the originality and clarity of his thought and writing and through his personal vigor and enthusiasm.

WARREN KENDALL LEWIS, twentieth Lamme medalist of this Society, was born at Laurel, Delaware on August 21, 1882. He was graduated from the Massachusetts Institute of Technology with the degree of Bachelor of Science in Chemical Engineering in 1905 and received his Doctor of Philosophy degree in Chemistry from the University of Breslau (Germany) in 1908. The honorary degree of Doctor of Science was bestowed upon him by the University of Delaware in 1937 and that of Doctor of Engineering by Princeton University in 1947.

Following his graduation from M.I.T., Lewis remained there for a year as Assistant in Industrial Chemistry and returned as Research Associate in Applied Chemistry upon completion of his graduate work in Germany. In 1909, he became chemist for the W. H. McElwain Company but the next year was appointed Assistant Professor at M.I.T. In 1912 he became Associate Professor and since 1914 has been Professor of Chemical Engineering at that institution. From 1920 to 1929, he was head of the Department of Chemical Engineering. During the first World War, he was on leave with the War Department's Chemical Warfare Service in charge of the coordination of research on gas defense. In World War II, in addition to carrying temporary responsibility for the Chemical Engineering Department at M.I.T., he acted as consultant for the National Defense Research Committee and served on several advisory boards for the Manhattan District.

His major consulting work has been with the Standard Oil Development Company, Humble Oil and Refining Company, Goodyear Tire and Rubber Company, Eastman Kodak Company, Freeport Sulphur Company, and the General Electric Company, as well as with a number of other large companies through the Institute's School of Chemical Engineering Practice.

Dr. Lewis' contributions to the theory and practice of chemical engineering stem from basic research and interpretation which he has initiated or guided in such fields as the flow of heat, the fundamental properties of fluids, their particular significance to hydrocarbons, the mathematical treatment of rectification, and the theory of vulcanization of rubber. His work has reaffirmed the utility of the generalized "equation" of state and has developed this theory as a working engineering tool through graphical manipulation of the relationships involved. It has demonstrated the mechanisms of interphase diffusion as they occur in rectification, extraction, absorption, drying and similar processes,

WARREN KENDALL LEWIS

Twentieth Recipient of Lamme Award

and has led to understanding of the mechanisms of combustion in solid fuels and of generation of producer gas.

Such fundamental work has led to noteworthy accomplishments in many industries such as petroleum, rubber, cellulose, and amorphous materials generally. Two examples of widespread industrial significance stand out. Lewis initiated the introduction of modern methods of distillation into the petroleum industry, where he proved that principles previously used in other industries could be adapted to the far more complex structure of petroleum. With Gilliland and others, he carried out underlying pioneering work and played a responsible part in the development of the fluid catalyst cracking process. The original concepts upon which this process is based were promulgated in 1938. First utilized on a large scale during the war for the production of aviation gasoline and synthetic rubber, this process now is also largely used for high quality. low cost motor gasoline. The plants employing it represent an investment of over $200,000,000 and additional plant is planned to provide 40 per cent more capacity within the next three years.

In 1936, the Perkin Medal for achievement in applied chemistry was awarded to Dr. Lewis by the American Section of the British Society of Chemical Industry.

In his teaching, Dr. Lewis constantly has sought effective ways to stimulate intellectual initiative in his students. In the classroom, through examples emphasizing both the quantitative and the qualitative elements in a problem, students are forced into situations where they must do analytical thinking of their own. Laboratory work is made a genuine investigative procedure and the research point of view is developed even in undergraduates through a required thesis. With a broad interest in and appreciation for physics and chemistry, he has taught vigorously the application of pure science to the solutions of the problems of chemical industry. His determination in overcoming obstacles in converting theory into practice and his personality and magnetism have led his students and younger associates to absorb some measure of his methods and have fired them with his enthusiasm and vision. His work in the development of the M.I.T. School of Chemical Engineering Practice has been a major contribution to engineering education.

The breadth of his interests and his capacity are well illustrated by the scope of his publications. In addition to a large number of technical papers, his publications include the book, "Principles of Chemical Engineering," with Walker and McAdams (1923 and 1927) and also with Gilliland (1937); "Industrial Stoichiometry," with Radasch (1926), and "Industrial Chemistry of Colloidal and Amorphous Materials," with Squires and Broughton (1942). The importance of "Principles of Chemical Engineering" as a milestone of progress can hardly be overestimated. It conveyed to the new profession the results of pioneering investigation. It gave the first adequate concept of the scope of the profession, and it defined and applied the fundamental engineering principle. Dr. Lewis' originality and genius for discovering and elucidating basic principles and for introducing quantitative treatment into a subject which had previously been purely qualitative shines throughout this work.

Dr. Lewis is a member of the American Chemical Society, Society of Chemical Industry, American Institute of

Chemical Engineers, American Institute of Mining and Metallurgical Engineers, American Leather Chemists Association, American Academy of Arts and Sciences, National Academy of Sciences, and an honorary member of the Institute of Chemical Engineers of Great Britain.

In 1909, he married Rosaline Denny Kenway. They have two sons and two daughters and their home is at 85 Lombard Street, Newton, Massachusetts.

RECIPIENTS OF A.S.E.E. LAMME MEDAL

1928—George Fillmore Swain
1929—Irving Porter Church
1930—Charles Felton Scott
1931—Dugald Caleb Jackson
1932—Arthur Newell Talbot
1933—Dexter Simpson Kimball
1934—Edward Rose Maurer
1935—William Elgin Wickenden
1936—Herman Schneider
1937—Frederick Eugene Turneaure
1938—Robert Lemuel Sackett
1939—Stephen P. Timoshenko
1940—Audrey A. Potter
1941—Anson Marston
1942—Roy Andrew Seaton
1943—Thomas Ewing French
1944—Hardy Cross
1945—Harry Parker Hammond
1946—Robert Ernest Doherty
1947—Warren Kendall Lewis

George Westinghouse Award—Benjamin Richard Teare, Jr.

To Benjamin Richard Teare, Jr.—for his invaluable work in the development of courses in engineering analysis; for his spirited support and ready cooperation in every worthwhile effort toward betterment of engineering education; and for the bracing influence on his students and fellow workers of the power of his attack on every new problem, the second George Westinghouse Award in Engineering Education is made.

Benjamin Richard Teare, Jr., known as "Dick" to a host of friends in education and in industry, was appointed to a full professorship at Carnegie Institute of Technology at the age of thirty-two. Five years later he became Buhl Professor and Head of the Department of Electrical Engineering. He has gained a national reputation for his pioneering work in the development and coordination of engineering courses.

In the field of engineering education, Dr. Teare has written important papers on Engineering Education. Notable among these are "Teaching Methods in Engineering Analysis" (Journal of Engineering Education, Vol. 35, June 1945) and "Planning the Professional Aspects of Humanistic and Social Courses" (Journal of Engineering Education, Vol. 37, December 1946). These papers discuss the development of power of analysis in students by means of engineering analysis courses set up specifically to this end and also by means of humanistic and social courses. The second paper uncovers valuable possibilities for further improvement of engineering education. Dr. Teare has also contributed to the committee work of the American Society for Engineering Education. He participated in the "Report of the Committee on Engineering Education After the War" which has proved to be a sound blueprint for the post-war adjustment of engineering colleges.

These important contributions to educational philosophy have made Dr. Teare no less warm to the human problems of hundreds of students in his department. Of his relationship with Dr. Teare one student writes, "His course in engineering analysis was inspiring, both for the wealth and depth of the material he presented, and for the force of his personality. He spends his time freely discussing the student's program and plans for the future; makes adjustments in special cases and seeks, by arousing enthusiasm for all subjects, to keep our interests well-rounded. Beyond all this he gives friendly personal advice which proves him to be as fine a man as he is an educator."

Dr. Teare's scholarly achievement is by no means confined to the development of educational methods. He is continuously active and has gained wide recognition in engineering research. Perhaps the most important of his engineering papers are "Skin Effect in Bimetallic Conductors" (*A.I.E.E. Transactions* 1943) which won national and district A.I.E.E. prizes in 1943 and "Theory of Hyste-

BENJAMIN RICHARD TEARE, JR

resis-Motor Torque" (*A.I.E.E. Transactions* 1940) which was given honorable mention by the A.I.E.E.

Dr. Teare, who was born on January 12, 1907 in Menomonie, Wisconsin, received his B.S. degree in Electrical Engineering (1927) and his Master's degree (1928) at the University of Wisconsin. In the fall of 1929, he joined the General Electric Company at Schenectady as a student in the Advanced Course in Engineering and continued for four years with the educational program while he obtained practical experience in many departments, including Testing, Research, Alternating Current Engineering, Central Station Engineering, and Engineering General. In 1931 he became supervisor of the electrical engineering section of the Advanced Courses in which he had started as a student two years before. At the end of two more years' work at Schenectady, Dr. Teare decided to enter the teaching field and accepted an instructorship in electrical engineering at Yale to work for his doctorate. He was promoted to as-

sistant professor of electrical engineering in 1934 and received his Doctor of Engineering degree in 1936. While getting his first experience in academic education at Yale, he was in close contact with Dr. Robert E. Doherty, then Dean of the School of Engineering, from whom he gained inspiration for many of his ideas on how engineers should be taught so that they develop to the utmost their capacity to think and to solve problems in an orderly way and above all so that they assume their proper responsibilities in society.

The war years found Dr. Teare serving as an electrical engineer in the Naval Ordnance Laboratory and working on research problems for the National Defense Research Committee, the Office of Scientific Research and Development, the Army Air Forces, and the Office of Naval Research.

During his years at Carnegie, Dr. Teare has served on many outside committees involving not only organizations in his own field of electrical engineering, but the Engineering Society of Western Pennsylvania, the American Standards Association, the Carnegie Foundation, the Institute of Radio Engineers, and the American Society for Engineering Education.

Dr. Teare holds membership in the following professional, honorary, and social societies: American Society for Engineering Education, American Institute of Electrical Engineers, Institute of Radio Engineers, Instrument Society of America, Sigma Xi, Tau Beta Pi, Eta Kappa Nu, Phi Kappa Phi, and Sigma Phi Epsilon. In 1932 he married Isabel Olbrich and they have one daughter. The Teares reside at 120 N. Homewood Avenue, Pittsburgh, Pennsylvania.

RECIPIENTS OF GEORGE WESTINGHOUSE AWARD

1946—James Norman Goodier
1947—Benjamin Richard Teare, Jr.

Turning Points

By CHARLES E. MACQUIGG
President of the Society

Turning points seem to occur so consistently and naturally in the careers of individuals and nations that we take them as a matter of course and sometimes they may even pass unnoticed at the moment. May they not also occur in the life of a Society like ours? These changes are harder to visualize in the case of a nation or society than in the affairs of an individual. With national life, only in sufficiently long retrospect is one able to say, "That trend started after the era of railroad expansion" or "This was the result of the automobile," and so on.

Possibly societies like ours undergo more or less abrupt shifts at least in their environments. While not as clear-cut as those attending the "inflection points" in the life of the individual, which is accented with some new emphasis in responsibilities, or change of residence or occupation, nevertheless there may be arrivals at periods in human destiny which must perforce bring new patterns of thought, or mass behavior which must in turn register effects on the life and objectives of an association. Certainly our Society was born at the time and place when the new era of electrification was coming into being. The World's Fair at Chicago may be looked upon as a great preview of a new era in our national existence. Then it was that countless thousands of us saw arc-lights for the first time—or the "naphtha" launch—or the life-like models of our "new Navy made of alloy steel." These sights must have affected the manufacturer or the banker much as the sight of a new mechanized agricultural implement affects the progressive farmer on his visit to the State Fair. Whether or not these thoughts occurred to the engineers who founded the Society for The Promotion of Engineering Education at Chicago in 1893, the teachers of engineers *did* orient themselves from the particular inflection point in human history and they *did* see a need connected with the guidance of engineering education and they *did* start to establish and maintain objectives towards higher levels of unified performance. ALL HONOR TO THEM.

No one can escape the implications of the changes in human affairs which have sprung from the years since 1941. Any World War will beget them, whether they be the influence on juvenile delinquency; the implications of increased alcoholic consumption; the new foreign policy, or the almost casual talk of the expected use of the Pile. We are at an inflection point and it would seem to be as fateful as any we may ever have experienced. What then of possible new tangents or new objectives for us? Certainly they should be only changes of emphasis and not total re-orientation or discarding of the old objectives; only re-dedication and here

and there an underscoring of an old principle. In other words, a pause to analyze the trends of the times and to reset our sights.

What are the likely changes or possible shifts in the incredibly complex alignments in human affairs as they may affect us as a Society and our place in the life of the nation?

Is the kind of education in which we are interested on the way to be differentiated between two distinctly different objectives? Will one of these objectives be a tendency toward more and more emphasis on the scientific principles which underlie the practice of engineering, i.e., the three fundamental tools of science with less emphasis on "product engineering"? Along such lines one might visualize three years of mathematics, physics and chemistry for *all* engineers, with only months of specialization and of non-vocational subjects with the understanding that curricula would be built up on a vertical integration through four or five years. One argument for this type of scheme may be found in the statistical fact that a significantly large percentage of graduated engineers do not practice the particular branch of engineering for which they were trained.

The other objective is indicated by a great demand for the technician type of individual who does not need the upper level of the abstract disciplines and actually is incapable of finishing the four or five year curriculum. These students should have a type of technical training between high school and college levels. This problem is already on the way to trial solution in several of the states and it may be vastly more general than heretofore expected.

Both of these questions have been under our active study, an evidence of the timeliness of our work.

The non-vocational aspects of higher education for engineers were mentioned above and the subject is still controversial with many of us in spite of eloquent appeals from our own members in the recent past. Some of our schools are bravely trying the solution of the problems involved, but although one may concede the educational correctness of the humanistic studies for the engineer, there still remains the question of how to carry out the details. Difficulties involving subject matter await solution because of the present pattern of presentation in our sister Arts colleges. Naturally these colleges have tended to develop specialists in sociology, psychology, history and so forth. In a manner, their course sequences have been built in a somewhat analogous pattern to those in engineering, namely, introductory courses and the usual upward trend towards specialization and into the graduate school. Our engineering student will hardly aspire to be a professional historian or teacher of history. Our problem is to work with the teachers of non-technical subjects to devise courses which will meet the following needs: (a) The subject matter must avoid too great an objective towards specialization; (b) The subject matter must avoid mere "fluff" and windy generalizations which certainly will not hold the interest of our students; (c) Broad outlines must be presented which will expand the mental horizon of the technical student and whet his appetite for knowledge of history, or law, or sociology, or biology, or political science, insofar as that broadening will better fit him for the duties of citizenship.

Recently a prominent industrialist

summed up the desirability of the proper blending of the vocational and the non-vocational by saying—"Recognition is given to the importance of many of the subjects commonly included in the curricula of a liberal college. Enough exposure to the main works of history and literature to acquire an interest in further reading and personal study is deemed "essential along with some understanding of accepted laws of economics, the type of thinking economists employ and our system of government and competing systems. Facility in the use of the English language with at least an introduction to a foreign language or two, is also essential." *

Graduate work is becoming more and more a sine qua non for the student of engineering who expects to teach or engage in research. Unfortunately all branches of engineering education have not been sufficiently aware of this fact and here is a challenge to our Society for discussion and recommendations.

Another and entirely different type of responsibility is also clearly ours, and that is the strengthening of what for lack of better words we may call the professional consciousness of the engineer. By this we do not mean the building of pressure groups, or clamorous minorities, but rather intelligent, conscientious, cooperative citizens aware of their professional status and *responsibilities* to society and capable of acting *as engineers* for the common good. This involves esprit de corps, in which we certainly are ahead of some other professions. Let us recognize and cherish this fine status by everything we can do. We can strengthen the morale and the class consciousness of our students by appealing to the *sense of responsibility* of the young engineer. This is no less real in our profession than it is with the medical profession, which has led the way since the time of Hippocrates.

The foregoing problems would seem to be among those which are facing us as a result of the confused ideas and trends in our world of today. The members of our Society have a great opportunity to work with the finest youth in this or any other land; our responsibility is to try to teach them to think properly and effectively because almost certainly the result of their thinking will be given more and more consideration by their fellows as time goes on. This challenge is ours: To better in every way our instruction in science and technology and above all to teach by example and precept that "man does not live by bread alone."

This greeting can best be closed on a note sounded by our beloved Dr. Bishop who the other day in a conversation said something like this—"I am constantly amazed by the strength and solidarity of our Society. It has a spirit of youth and esprit de corps which is wonderful."

* "Basic Sciences and Technology Plus Liberal Courses Produce Well Rounded Engineers." D. H. McLaughlin, *Mining & Metallurgy*, July, 1947, Am. Inst. Min. & Met. Engrs.

Engineering Education for an Atomic Age*

By HUBER O. CROFT

President, American Society for Engineering Education; Professor and Head, Dept. of Mechanical Engineering, State University of Iowa

You and I are unique, for we are of the age trans-Hiroshimo. Most certainly you and I are unique in the sense that we are witnesses at the trial for survival of our own civilization. The records of this trial are not hurriedly registered by the swiftly moving pen, or the impact of a stenotype of the professional court recorder. On the contrary, unfortunately for us the record of this trial is slowly and painstakingly chronicled by that professional group known as historians. The errors we make during our trial cannot be corrected but they definitely will be recorded. So we must do our utmost to prevent error during this trial.

We can approach this entirely new situation which we face in three ways:

First, we can ignore the facts and refuse to imagine the consequences.

Second, we can recognize the facts, continue on our merry way, and remain comfortably complacent doing nothing.

Third, we can recognize the discomforting facts, and as patriotic, educated Americans do our utmost to prevent the historical recording of a lurid catastrophe, at least in our time.

I am sure that most of this group will be numbered under the third and last classification. The question then becomes how can we as educators do our share to preserve the most desirable features of this civilization which our forefathers contrived and we and our fellow citizens now enjoy.

Isn't it strange that we live in a world which has spent billions of dollars to determine accurately the varied equations for nuclear fission and for the design and construction of machinery to promote and control nuclear fission while, at the same time, the amount of money, which we spend to investigate the human equations expressing the delicate relationships between nations, is negligible. If nature's physical laws are stubborn to discover, the laws of human nature, if any, are even more obstinate of revelation. It has taken more than two thousand years and boundless wealth for the periodic table of the chemical elements to be changed from the four pre-Aristotelian elements of earth, water, air and fire to the 92 elements of the pre-Hiroshimo periodic table. If there is time, no doubt at some future date a genius will propose a periodic table for the human elements that constitute national pressures for war and for Peace. Perhaps then, after being given proper directions, humans will wish to become humanitarian. I merely suggest that such a periodic table of human elements should perhaps be worth the expenditure of at least one Oak Ridge.

* Presidential address delivered at the 55th annual meeting, A.S.E.E., Minneapolis, June 17–21, 1947.

Naturally such a table as this would take years to complete but we must do our part now. We as educators simply must exert our influence for preservation of the world in which we find ourselves. This means that we must deliberately plan to train intensively for three-fold possibilities:

(1) Engineering and Science.
(2) National and Civic Service.
(3) International Understanding.

Obviously, we ought to afford to offer the finest, most complete, and most progressive undergraduate courses that can be conceived, but we must do more, for it is essential that we encourage our best young men to undertake graduate work to make certain that our nation will have a sufficient reservoir of research workers, not to compete with, but to surpass any possible world competitor, in discovering and applying scientific facts. Competition is the spice of life to be sure, but being second best in A-bomb competition may mean the end of life for us.

To implement this need undoubtedly, the National Research Foundation bill will be passed by Congress in one form or another. Are you studying your own situation to determine how you and your own institution may assist in carrying out the expressed objectives of this bill and will you encourage a few of your best men to follow the postgraduate path to become skilled research men? I sincerely hope that you will.

But in these days, the training of mere efficient slide-rule engineers is neither in tempo nor in tune with our time. On all sides we see misunderstanding, disagreement and dispute prevailing and, unfortunately, at all levels of human organization whether it be the butcher shop down on the corner, the telephone system which blankets the country, or the tête-à-tête of Mr. Marshall and Mr. Molotov.

While this unrest is natural following the greatest war in history, our students should at least know and recognize the underlying forces at work because our students are to be engineers, yes, but they are also citizens and they should vote intelligently. Furthermore, many of them may find themselves precisely in the middle of an industrial dispute which they may be called upon to arbitrate.

To me, and I hope to you, it is apparent that our students before they graduate must have at least an elementary background for active and intelligent citizenship in our complex republic. In the undergraduate years, introduction of wisely selected courses in the humanities, as has been recommended by committees of our Society, will assist in giving the necessary background. Stimulation to read serious works on the national and international problems of the day will also assist in forming the maturity of judgment we desire for our graduates. To stimulate an undergraduate student to read worthy non-technical books without receiving registrar's academic credit is a challenge to, as well as a test of good engineering teaching. I am one of that group which believes that the undergraduate degree course must be increased to five years of study, which, among other advantages, would give an elementary background for the civic leadership which is expected of engineers. I fully realize that there are those just as firm in their belief that four years of training is sufficient. Time only will prove the solution to the questions at issue.

But specifying a course of study in exact detail for a citizen engineer is not

enough. Sincere and sympathetic encouragment to engage in civil affairs should be presented to the entering freshman engineer, and this should be continued until he graduates. This encouragement should be continued by his employer for only by attending caucases, council meetings, political rallies, and sessions of legislatures and congress does one gain a real and practical understanding of the functioning of our great government. It seems quite clear to me, that the time has come for engineers to stop sneering at politics. The country needs intelligent, trained, honest leaders as never before. It is our patriotic, bounden duty as educators and industrial leaders to heed this urgent demand.

And finally what of the Atom-bomb, which we know how to construct quite well, and of international good will, which we know how to construct, much less well?

It is probably true that we are the wealthiest, the best nourished, the most productive, the most powerful, and outside of our own borders, the most feared nation in the world today. We should also realize that we are the most conservative of all nations holding free elections. It makes little difference if our external moves are stimulated by the inherent idealism of our people—there is always the thought in the minds of citizens of other countries, that underlying our generosity is some sinister, ulterior motive. Discussions with Americans who know and understand foreign countries will substantiate these facts. A thinking man knows that the reactions to fear are irrational and automatic.

The United Nations sensing the need for international understanding has made a start toward this goal. One of the most satisfying experiences of my life has been that as your representative on the First National Advisory Committee of UNESCO, the United Nations Educational, Scientific, and Cultural Organization. This group, authorized by Congress, is one of similar bodies working in most of the member nations of the United Nations to promote Peace, Good Will, and Mutual Understanding between the peoples of the world. What UNESCO lacks in budget is compensated for at least partially by the sincere enthusiasm of its members. All of us hope, I am sure, that UNESCO will succeed in its fundamental objectives.

Now what can we as educators do to alleviate this natural but difficult situation? It seems to me quite obvious that the first step for us to take is to encourage the exchange of more and more students and faculty from outside our borders.

It was through the inspiration of UNESCO that I took the liberty of asking the State Department to send an invitation through each of their consular offices to every country with whom we maintain diplomatic relations. The invitation to attend this meeting in Minneapolis was extended to a prominent engineering educator in each country. The first approach was made to the State Department in December but, for various reasons, the invitations were not sent to the consular offices abroad until April. Dr. Dowdell of the University of Minneapolis was asked to be the liaison official here for all foreign guests. He advises me this morning that 16 guests from foreign shores are among us this morning, and we hope there will be many more before the session closes. It seems to me that invitations to our colleagues abroad, and one session of the annual meeting during which our

guests may talk to us about their hopes and aspirations, and their problems should be an annual tradition. This is one way we as a Society may really contribute to international appreciation and understanding.

May I summarize briefly: First: we must strive to improve our present undergraduate curricula and to prepare our graduates with a knowledge of national and world problems as well as in technical learning. We must induce more carefully selected men to undertake graduate work, not only because it will open greater professional possibilities but also because our country needs them desperately. Second: if we really believe that engineers are intelligent and useful citizens of the state, we should not only contrive curricula that will give them at least a background for a working citizenship, but further we should encourage engineers actively to engage in political service to our nation.

And lastly: the exchange of students and scholars from overseas will contribute much to demonstrate our idealism and good will and furthermore we can demonstrate that at least the rank and file of our citizens do not wish for an A-bomb in their pockets.

General Council, A.S.E.E. 1947-1948

OFFICERS

President

C. E. MacQuigg, The Ohio State University, Columbus 10, Ohio

Vice Presidents

J. B. Robertson, University of Minnesota, Minneapolis, Minnesota (In charge of general and regional activities)
C. J. Freund, University of Detroit, Detroit, Michigan (In charge of instructional divisional activities)
S. S. Steinberg, University of Maryland, College Park, Maryland (Engineering College Administrative Council)
F. M. Dawson, State University of Iowa, Iowa City, Iowa (Engineering College Research Council)

Secretary

F. L. Bishop, University of Pittsburgh, Pittsburgh, Pennsylvania

Treasurer

J. S. Thompson, McGraw-Hill Book Co., New York 18, New York

Assistant Secretary

Nell McKenry, University of Pittsburgh, Pittsburgh, Pennsylvania

Junior Past Presidents

H. O. Croft, University of Iowa, Iowa City, Iowa
H. S. Rogers, Polytechnic Institute of Brooklyn, Brooklyn, New York
R. E. Doherty, Carnegie Institute of Technology, Pittsburgh, Pennsylvania

DIVISIONS

Representatives on Council

Aeronautical—H. W. Barlow, A. & M. College, Texas, College Station, Texas. **2 years.**

Agricultural Engineering—A. W. Turner, Agricultural Research Center, Beltsville, Maryland. **1 year.**

Chemical Engineering—J. H. Koffolt, The Ohio State University, Columbus, Ohio. **2 years.**

Civil Engineering—L. S. LeTellier, The Citadel, Charleston, South Carolina. **1 year.**

Cooperative Engineering—H. K. Justice, University of Cincinnati, Cincinnati, Ohio. **2 years.**

Educational Methods—W. C. White, Northeastern University, Boston, Massachusetts. **1 year.**

Electrical Engineering—C. G. Brennecke, North Carolina State College, Raleigh, N. C. **2 years.**

Engineering Drawing—F. G. Higbee, University of Iowa, Iowa City, Iowa. **1 year.**

English—J. E. Thornton, University of Michigan, Ann Arbor, Michigan. **2 years.**

Graduate Studies—S. C. Lind, University of Minnesota, Minneapolis, Minnesota. **1 year.**

Humanistic-Social—E. S. Burdell, Cooper Union, New York, New York. **2 years.**

Industrial Engineering—P. N. Lehoczky, The Ohio State University, Columbus, Ohio. **1 year.**

Mathematics—J. H. Zant, Oklahoma A. & M. College, Okmulgee, Oklahoma. **2 years.**

Mechanical Engineering—B. E. Short, University of Texas, Austin, Texas. **1 year.**

Mechanics—R. V. James, University of Oklahoma, Norman, Oklahoma. **2 years.**

Mineral Engineering—W. B. Plank, Lafayette College, Easton, Pennsylvania. **1 year.**

Physics—J. G. Potter, A. & M. College of Texas, College Station, Texas. **2 years.**

Technical Institutes—W. L. Hughes, Franklin Technical Institute, Boston, Massachusetts. **1 year.**

Allegheny—D. F. Miner, Carnegie Institute of Technology, Pittsburgh, Pennsylvania. **2 years.**

Illinois-Indiana—W. M. Lansford, University of Illinois, Urbana, Illinois. **1 year.**

Kansas-Nebraska—

Michigan—T. C. Hanson, University of Detroit, Detroit, Michigan. **1 year.**

Middle-Atlantic—

Missouri—

National Capital.—H. H. Armsby, U. S. Dept. of Education, Washington, D. C. **1 year.**

New England—

North Midwest—L. O. Stewart, Iowa State College, Ames, Iowa. **1 year.**

Ohio—O. M. Stone, Case Institute of Technology, Cleveland, Ohio. **2 years.**

Pacific Northwest—Harry McIntyre, University of Washington, Seattle, Washington. **1 year.**

Pacific Southwest—

Rocky Mountain—W. O. Birl., University of Colorado, Boulder, Colorado. **1 year.**

Southeastern—L. J. Lassalle, Louisiana State University, University, Louisiana. **2 years.**

Southwestern—W. R. Woolrich, University of Texas, Austin, Texas. **1 year.**

Upper New York—

Report on Sections

By EARLE B. NORRIS
Vice President

This report must, of necessity, represent merely the ideas of your Vice President, since it is called for before the Committee on Sections and Branches has had opportunity to meet and to prepare recommendations.

Section activities have assumed increasing importance in the value of the Society to its membership. Section meetings serve a far greater percentage of the membership than does the annual meeting of the national organization and they reach to the grassroots of the Society. The Constitution provides that "A section of the Society may be formed by members in two or more institutions within a territory prescribed by the General Council." This sounds as if a section might consist only of members associated with the faculties of the institutions which set up the section. It is my personal feeling that, where the General Council has prescribed the territorial limits of a section, we should consider that all members within those limits should be included in the section membership. This practice could give professional engineers and industrial representatives a greater usefulness to the Society and a greater sense of belonging. Likewise, faculty members of technical institutions (Affiliate Members) would benefit from the opportunity to share in the programs of the section meetings. If this idea is sound it becomes necessary that exact boundaries be fixed for each section. However, I find the practice quite common of visiting back and forth between sections. This is a wholesome practice to be encouraged. Therefore, I suggest that section boundaries should be inclusive, but not exclusive.

There are some institutions and some whole states not within any section as now defined and established. Since the Constitution provides that the initiative for the formation of sections lies in the institutions, the Council is not in a position to dictate, but it may well make suggestions for consideration. The people in the Dakotas are at present without any sectional affiliation. They have no North or South means of rail travel, but all have convenient routes to Minneapolis and thence into Wisconsin and Iowa. It is, therefore, suggested that the North Midwest Section be asked to include in its area all of North Dakota and South Dakota east of the Missouri River. The South Dakota School of Mines is much nearer to and perhaps more closely allied economically with the schools in Wyoming and Colorado. It is, therefore, suggested that the Area of South Dakota west of the Missouri River be assigned to the Rocky Mountain Section.

Utah is another orphan state, with its two state institutions and with two members at Weber College and a few professional engineers in Salt Lake City. In all, there are but 22 members in the state of Utah. Doubtless, some section activity might result in an increased interest. Dean Taylor at the

University thinks that they are officially supposed to be in the Southwest Pacific Section with California, Nevada and Arizona. If so, the officers of that section do not seem to know it and Dean Taylor says rightly that the distances are too great. I suggest a trial of assigning Utah to the Rocky Mountain Section, with the organization of a Utah Section as the alternative.

Arkansas is another orphan state. Dean Stocker tells me that at one time Arkansas and Oklahoma were in a section of their own. The Oklahoma Schools joined with Texas and New Mexico in the Southwestern Section and left Arkansas alone on the outside. They visit nearby sections when convenient, having taken in a meeting of the Missouri Section at Rolla and of the Southeastern Section in Louisville. Since Fayetteville is so near the Missouri border, inclusion with Missouri in a Missouri-Arkansas Section would seem logical. Here, again, I feel that the initiative should come from the schools and not from the Council of the Society. The Kansas-Nebraska Section suggested a change in name to the Missouri Valley Section, but this would be confusing so long as there is also a Missouri Section. There appeared to be some doubt as to the Sectional affiliation of the Michigan College of Mines and Technology at Houghton in the Upper Peninsula. After some correspondence it appears that the sentiment favored inclusion in the Michigan Section and I believe that such reunion took place this spring. In this connection, I would repeat my feeling that we should encourage visiting across sectional borders and that such exchanges of hospitality and courtesy should not require any change of sectional affiliation.

So far as I know there is no attempt at Sectional organization in Canada. It might be well to suggest that the Upper New York Section invite the Toronto, Montreal and Quebec schools to their meetings with the aim either of permanent affiliation or of stimulating the creation of an Ontario-Quebec Section.

The Maritime Provinces might also form a section of their own.

British Columbia might readily be included in our Pacific Northwest Section.

That leaves the Universities of Manitoba, Alberta and Saskatchewan spread out over a distance of 827 miles by rail, and with but one member in each school. That distance is, however, no greater than the extent of some of the sections in the United States if we could stimulate more interest and an increased membership.

Branches

During the year the Purdue Branch has surrendered its status as such by reason of the fact that the Illinois-Indiana Section and the Engineering Faculty meetings at Purdue seem to cover the problems originally intended to be considered by the Branch.

In Minnesota we had a Section listed although its membership was from the University. This section has asked that it become a Branch and that Minnesota be included in the North-Midwest Section.

Believing that the spirit of our Sectional organization, as well as the letter of our Constitution places the initiative for sectional organization with the institutions concerned, I am making no recommendations to the Council other than that my successor might communicate my suggestions to the schools and sections concerned for their consideration and possible action.

Report of the Secretary, F. L. Bishop, for 1946–47

The Constitution of the American Society for Engineering Education provides for three Councils, namely, the General Council, the Engineering College Administrative Council, and the Engineering College Research Council. This is a report to the General Council. This Council is composed of officers of the Society and representatives from every division and section. These representatives serve for a period of two years under the plan of rotation in which one-half of each group will be chosen each year.

In general, the new Constitution of the Society has proved satisfactory although there are minor changes which should be carefully considered by the Committee on the Revision of the Constitution.

The Constitution assigns to this Council specifically the problems pertaining to teaching. The greatly increased attendance in engineering colleges and the large number of new and inexperienced teachers in the colleges have increased very materially all old problems of instruction and created many new ones. It is the duty of this Council to assist on the solution of these problems.

Membership. The present members of the Society is 4,820 of which 165 are institutional members. There have been elected 887 new members through the efforts of the Membership Committee under the chairmanship of President Croft. This Committee was composed of one member from each state who selected aides from the different colleges. This is the largest number of new members to be elected in a single year. The distribution of new members is interesting. There are approximately:

	per cent	Total membership per cent
Instructors	30	10
Assistant professors	21	15
Associate professors	12	16
Professors	12	32
Presidents and deans	13	11
Industry	10	14
Miscellaneous	2	2

We have lost 17 by death, T. R. Agg, W. N. Barnard, E. S. Gray, M. E. Holmes, S. S. Garrett, G. A. Maney, P. C. Nash, J. T. L. McNew, R. G. Paustian, T. T. Read, A. J. Tremblay, D. M. Russell, Albert Siepert, H. W. Waterfall, C. C. Williams, F. C. Stockwell; 252 by resignation.

With the greatly increased faculties required in the engineering colleges it seems as though we might look forward to a large increase in membership next year.

The various sections, divisions and committees have been doing notable work throughout the year. Some of these results are indicated by the program of the conferences. One of the notable contributions is the summer school for mechanical engineers held at Northwestern University just prior to this meeting.

Section meetings were curtailed during the period of the war. These meetings have in most cases been resumed. The attendance and interest have been exceptional. The papers presented were excellent and some have been printed in the JOURNAL. We shall

hear more detailed reports from the section representatives.

President Croft has been very generous in giving his time to attend the sectional meetings. This is an important duty of the President.

President Croft will make a report to you in regard to the various ballots which he has taken during the year.

Publications. The shortage of paper and labor troubles made it rather difficult to issue the JOURNAL and in almost every case it was delayed for these reasons. The cost of the JOURNAL has greatly increased over a period of years and especially during the past year.

Enrollment figures were obtained in the usual way by this office but several institutions failed to make returns, among them were some of the larger institutions. Dean H. P. Hammond has been making a study of enrollments for other purposes and found that statistics given us were not the same as those given to him. You will be interested in the following figures which he gives:

"The JOURNAL's tabulation is based on 130 American schools, which omits about 25 schools, including such large ones as Illinois, Missouri, CCNY, Lehigh, George Washington, and Oklahoma A. & M. I have estimated the 1946–47 enrollments of these schools by taking their own predictions of enrollments for 1947–48 and reducing these by the average increase we have found between 1946–47 and 1947–48 from reports from over one hundred institutions. While the result is subject to error, caused by this method of estimation, nevertheless it does give a rough approximation of the total number of students. My estimates indicate that the total enrollment of undergraduates in schools in the United States for 1946–47 was about 222,000 and, including graduates, about 236,000." (Our figures were 197,797 undergraduates.)

Report of the Treasurer for 1946–47, J. S. Thompson

AMERICAN SOCIETY FOR ENGINEERING EDUCATION
COMPARATIVE STATEMENT OF CASH ACCOUNT
June 12, 1947

	1945–46 (June 12, 1946)	1946–47 (June 12, 1947)
BALANCE ON HAND:		
Forbes National Bank—Checking Account	$13,227.07	$16,115.93
Forbes National Bank—Savings Account	639.25	
	$13,866.32	$16,115.93
RECEIPTS:		
Current Dues	$17,346.41	$23,519.23
Back Dues	1,560.00	2,022.50
Dues in Advance	517.50	675.50
Sales of Publications	1,002.17	1,071.04
Advertising	4,304.02	5,032.76
Sale of Emblems	12.25	1.25
Interest on Savings Account	3.20	—
Interest on Government Bonds	258.75	351.25
Refund—Humanistic-Social Studies	164.40	—
Refund—to Close Summer Session Account	104.77	—
Receipts from Dinners	371.00	—
Refund on Gold Emblems	—	91.43
Westinghouse Educational Foundation	—	250.00
General Education Board Southeast Sec.	—	10,000.00
Carnegie Corp. ECAC Survey on Eng. Salaries	—	6,000.00
Total Receipts	$25,644.47	$49,014.96
DISBURSEMENTS:		
Cost of Publications	$10,474.28	$13,201.33
Honorarium for Secretary	2,000.00	2,200.00
Clerical Assistance	4,172.25	4,500.00
Travel and Entertainment, Secretary's Office	407.62	286.96
Printing, Postage, Office Supplies, etc.	986.20	2,063.93
Purchase of Equipment	648.78	—
Dues—American Council on Education	100.00	100.00
Contribution to Engineers' Council for Professional Development	750.00	650.00
Officers' Traveling Expenses	477.83	663.51
Expenses—1945 Meeting	153.85	—
Expenses—1946 Meeting	410.22	600.61
Expenses—1947 Meeting	—	1,166.25
Expenses—ECAC	520.17	828.22
Expenses—Revision of Constitution	390.89	—
Expenses—Committees and Conferences	711.15	670.82
Council Meeting	335.35	—
Purchase Series G Government Bonds	700.00	5,000.00
Expenses—Westinghouse Award	—	357.10
Emergency Expense	—	735.00
Va. Poly. Inst. for Manual	—	200.00
Total Disbursements	$23,394.86	$33,523.61

Balance on Hand:		
Forbes National Bank—Checking Account	$16,115.93	$31,607.28
Total Balance on Hand	$16,115.93	$31,607.28

American Society for Engineering Education
Comparative Statement of Income and Expense
For the Years Ending June 30, 1946 and 1947

	1945–46 (June 12, 1946)	1946–47 (June 12, 1947)
Income.		
Current Dues	$18,581.41	$25,036.73
Back Dues	560.00	1,022.50
Sale of Publications	1,002.17	1,071.04
Advertising	4,404.02	5,332.76
Sales of Emblems	12.25	1.25
Refund on Gold Emblems	—	91.43
Interest on Savings Account	3.20	—
Interest on Government Bonds	258.75	326.25
Refund to Close Summer School Account	104.77	—
Receipts for Dinners	371.00	—
Total Income	$25,297.57	$32,881.96
Expense:		
Cost of Publications	$10,274.28	$13,832.71
Expenses—1945 Meeting in 1946	213.02	1,010.83
Honorarium for Secretary	2,000.00	2,200.00
Clerical Assistance	4,172.25	4,500.00
Printing, Postage, Office Supplies, etc	986.20	2,063.93
Travel and Entertainment—Secretary's Office	407.62	286.96
Dues—American Council on Education	100.00	100.00
Contribution to Engineers' Council for Professional Development	750.00	650.00
Officers' Traveling Expenses	477.83	663.51
Expenses—ECAC	520.17	828.22
Expenses—Civil Engineering Division	156.27	299.88
Expenses—Conference on Social Humanities Problems	295.60	—
Expenses—Revision of Constitution	390.89	—
Expenses—Committees and Conferences	711.15	670.82
Council Meeting	335.35	—
Emergency Expense	—	735.00
Va. Poly. Inst. for Manual	—	200.00
Total Expense	$21,790.63	$28,041.86
Surplus for the Year	3,506.94	4,840.10
Total	$25,297.57	$32,881.96

AMERICAN SOCIETY FOR ENGINEERING EDUCATION
COMPARATIVE BALANCE SHEET
As of June 30, 1946 and 1947

ASSETS

	1946 (June 12, 1946)	1947 (June 12, 1947)
Cash:		
Current Fund	$16,115.93	$31,582.28
Petty Cash Fund	300.00	300.00
Life Membership Fund	1,045.92	78.40
Total Cash	$17,461.85	$31,960.68
United States Government Series G Bonds		
Current Account	$10,700.00	$15,700.00
Life Membership Fund	—	1,000.00
Total Bonds	$10,700.00	$16,700.00
B. J. Lamme Trust Fund:		
Securities and Mortgages	$ 5,108.41	$ 5,093.25
Uninvested Cash	35.84	51.00
Checking Account	178.54	204.45
Total Lamme Fund	$ 5,322.79	$ 5,348.70
Prepaid Expenses:		
1946 Meeting (1947)	$ 410.22	$ 1,166.25
Inventory (Nominal)	1.00	1.00
Accounts Receivable:		
Advertising	1,200.00	1,500.00
Dues	1,000.00	1,000.00
Westinghouse Educational Foundation	—	107.10
B. J. Lamme Award	191.49	—
Furniture and Fixtures (Nominal)	748.78	748.78
Total Assets	$37,036.13	$58,532.51

LIABILITIES

	1946	1947
Life Membership Fund	$ 1,045.92	$ 1,078.40
B. J. Lamme Trust Fund	5,322.79	5,348.70
Prepaid Membership Dues	517.50	675.50
General Education Board for Southeast Section	—	10,000.00
Carnegie Corporation for ECAC	—	6,000.00
Total Liabilities	$ 8,886.21	$25,733.98

SURPLUS ACCOUNT

	1946	1947
Balance	$24,642.98	$28,149.92
Less—Cancellation Account Receivable Lamme Award	—	191.49
Revised Balance	$24,642.98	$27,958.43
Surplus for Year	3,506.94	4,840.10
Total Liabilities and Surplus	$37,036.13	$58,532.51

Report on the Engineering College Administrative Council

During the past year the Administrative Council sought to establish a pattern for the operation of this division of the Society. Its executive committee, which met in the fall in Washington, in December in Chicago, and in June in Minneapolis, approved and started the following projects:

(1) The publication of a bulletin, which was handled by Dean W. C. White, the Secretary of the Administrative Council. The object of this bulletin has been to present topics of general interest to administrators of American engineering colleges and to serve as a medium of exchange among officers of these institutions.

(2) The completion, discussion, and distribution of a report on Academic Tenure, Professional Service and Responsibility prepared by a committee under the chairmanship of C. J. Freund. Responses from college officers commenting on this report bear testimony to its influence.

(3) A study of the problem of faculty salaries in engineering colleges. The executive committee enlisted the assistance of Dr. Dugald C. Jackson to undertake this study, and he presents a first report at the second general session of this convention. A notably high return on the information requested was obtained from the colleges, and the report therefore represents the most complete available information on this subject.

To extend this study and to obtain relative data on other types of organizations employing professional people, the executive committee sought extra funds, and as a result of a proposal to the Carnegie Corporation of New York the Administrative Council has received a grant of $6,000 for this purpose. During the coming year, therefore, the study of salaries will be continued under Dr. Jackson's direction, and information will be sought from other professional schools and from industry.

(4) A study of the problems involved in the transfer of students from emergency institutions to engineering colleges. Dean Harry P. Hammond undertook the chairmanship of a committee to study this problem, and this group carried through a remarkably detailed survey of present problems in enrollment. A notable report of its findings was presented at the second general session of the Minneapolis convention.

(5) A study of the problem of ROTC programs in engineering colleges. This resulted in a full session on this subject as a part of the program of the Minneapolis meeting.

During the year, the Administrative Council's Committee on Military Training Programs, under Dean Thorndike Saville, was very active and collaborated with the Engineering College Research Council in the study in Washington of Federal legislation affecting engineering colleges.

Representatives of the Administrative Council were afforded an opportunity by the Army to inspect the Universal Military Training Experimental Unit at Fort Knox.

The Administrative Council operated on a budget of $1,850 for the past year, and it now appears that this amount substantially represents its expenditures.

The President of the Administrative Council expresses his appreciation for the effective work of the executive committee of the Council and of the various subcommittees which were appointed. They formulated and carried through a program for the Council which I think it is fair to say continues it as an effective instrument for the assistance of our engineering college administrators. The chairman wishes especially to express his appreciation to Dean W. C. White, who carried out the work of Secretary with great efficiency and at all times kept the President alerted to what should be done and how it should be done.

Respectfully submitted,

J. R. KILLIAN, JR.,
President

Report of the President of the Engineering College Research Council

This 1947 Annual Meeting marks the end of the first year of formal affiliation between the Engineering College Research Council and The American Society for Engineering Education. At the annual meeting of the Engineering College Research Association one year ago in St. Louis, the Secretary of the Association announced the approval by our membership of a general proposal to merge the Research Association into the reorganization of the Society for the Promotion of Engineering Education, as the Engineering College Research Council of the American Society for Engineering Education.

At that time a Committee was appointed to formalize the terms of this affiliation; the report of this Committee, in the form of By-Laws for the Engineering College Research Council, was accepted late last year by our membership and became effective on January 1. Every effort was made to carry out the commission of the members of the Engineering College Research Association expressed at the 1946 Annual Meeting. Thus the E.C.R.C. is able to carry on autonomously in its public relationships and its publications program. We have an effective union with the A.S.E.E.: the President of the Research Council is a member of the Executive Board of the A.S.E.E. we report to the President of the Society, and our financial arrangements are coordinated with those of the Society by the Society's Treasurer. After one year's experience, we feel certain that the original objectives of the Research Association will not be submerged but very considerably brightened by the affiliation activated during the year. I firmly believe that, while the full promise of our new relationship with the A.S.E.E. has not yet been realized, the first year has given strong evidence that this new relationship can be of great benefit to both organizations.

To support this conclusion and to make a proper report to the members of the A.S.E.E., I want to review briefly the activities with which the Research Council has been occupied during the past twelve months. Our work has centered around our three principle committees; in addition, and in conjunction with the work of these committees, we have carried on an active and independent publications program.

Our Committee on Relations with Federal Research Agencies is authorized to act in an advisory capacity to any government agency in furthering cooperative research between that agency and any members of the Research Council. It is also authorized to undertake to advise a federal research agency as to institutions which are adequately equipped to perform research of a stated character. Through this committee in past years we have

made valuable contacts with the directors of a number of government-sponsored research programs. These contacts have been furthered this year. In addition, the Committee has assisted several branches of the Armed Services in obtaining detailed information from our member institutions about research facilities and interests in certain specialized fields. By invitation, several representatives of our member institutions had the unusual opportunity of visiting the Army Ground Forces Winter Test Task Forces in Wisconsin and Alaska, and their reports have been circulated to our membership. It is evident that the attitude of the engineering colleges toward research and research training has been neither completely understood nor accepted by some of those directing government research programs. It is equally clear that difficulties and misunderstandings exist in matters of technical contractual relations between colleges and government agencies. The future work of our Committee on Relations with Federal Research Agencies in both these fields should be helpful.

Establishment of the National Science Foundation, if it is approved by Congress, will bring additional problems of government liaison, which I believe the Research Council will be well prepared to accept.

As a result of changing emphasis from war-time to peace-time engineering research, a Committee on Relations with Industrial Research Groups was activated by the Research Council following the annual meeting last year, and in its first year of service this Committee has already discovered many opportunities for important service. After reaching some conclusions as to the policies and attitudes of the engineering colleges toward research sponsored by private industries, the Committee sponsored a most successful roundtable Tuesday evening of this week on the subject of "The Relation of College Research Organization to Industry." The Committee is now considering plans to help bring an understanding of college research policies and attitudes to the attention of industrial groups. At the same time the Committee will return to us with information about the desires and requirements of industry. I believe that this program for mutual understanding can go far to extend the value and scope of the research investigation and training which engineering colleges perform for industry.

As most of you know, for several years the Engineering College Research Association was active in support of the interests of the engineering profession in the proposed National Science Foundation. One of the first fruits of the affiliation between the Society and the Research Council came early this year with the appointment of a Joint Committee on Federal Legislation, in conjunction with the Administrative Council. Dean Saville will follow on this program with a brief report on the National Science Foundation bill, thus far our major legislative interest. Later Dean Norris will speak of another bill now before the Senate. The membership of the Research Council has been kept in touch with developments on these matters by a large number of circular letters from the Secretary's office. I believe we have made a substantial contribution to the success of the National Science Foundation bills, and I am certain that the groundwork has been laid for more complete representation of the interests of engineering education in legislative matters.

To supplement the activities of the various committees, the Research Council throughout this year has carried on an active publications program. Early in the fall the papers from the last annual meeting of the Association were assembled and published as Proceedings, and these have had circulation among industrial firms and the technical press as well as our member organizations. During the winter there was published a mimeographed book entitled "Exhibit of Patent Policies in 22 Colleges and Universities," which actually contained statements of patent policies from 24 member institutions. The Executive Committee has just authorized the reprinting and further distribution of this publication, and we hope to make copies available to all institutional members of the Society who may be interested.

At its annual business meeting last Wednesday, the Research Council announced publication of a new "Directory of Member Institutions and Review of Current Research." This publication, which has constituted the major project of the Secretary's office since March, undertakes to give a brief summary of research and contract policies at each member institution and indicates the fields in which each is particularly active in research, normally by giving a list of current research projects. We have distributed a number of copies at the meetings so far, and some have undoubtedly seen the new book. I might add that it has been accorded a very warm welcome, for which we are most gratified. Yesterday morning the Executive Board of the Society authorized its reprinting for distribution to all the industrial research laboratories listed in the National Research Council Bluebook. While we are anxious to prevent waste of the present edition, there are copies on the table here for general distribution to research officers and others who may be interested at the close of this session.

The end of the war has resulted in decreased high-pressuring of engineering research and increasing interest in fundamental research problems. We all suspect that this is a most healthy influence. Despite the pressure of greater teaching loads, the year has brought in general a most favorable climate for research activities in engineering colleges. I see no reason to fear that this favorable climate cannot continue. The nation is conscious of the importance of scientific research as never before, and particularly in the field of basic research much psychological and some financial support is happily available. In this respect, the possibility of a National Science Foundation cannot be underestimated.

This is not to say that serious problems do not remain for engineering colleges active in research. Many of our members are relatively new in the business of directing and supervising engineering research; some are doing engineering research on a peace-time basis almost for the first time. We hope soon to bring into more active association with the Research Council many institutional members of the Society whose research activities do not qualify them for full membership in the Research Council. All of these groups are actively seeking solutions to a number of mutual problems, by mutually comparing experiences and results. The wide interest during the week just ending in the sessions of the Research Council, and other Society sessions dealing with research, is evidence of our present curiosity. The potential role of the Research Council is obvious.

The Constitution of the A.S.E.E. lists four primary purposes of the Council: (1) To further advanced study and research (both fundamental and applied) in engineering colleges; (2) To undertake sponsorship of such research to promote advancement of education and the profession; (3) To represent its members in cooperative work with associations and government agencies; and (4) To publish periodic reports of value to engineering research. I am very happy to report that, on the basis of our first year's activities, I believe our affiliation with the A.S.E.E. gives promise that these purposes can and will be achieved in full measure. I am certain that our activities this year represented substantial progress toward our goal. I look forward to the years ahead with confidence that the Research Council will further prove its importance to the cause of engineering research and to the broad profession of engineering.

Report of Committee on Transfer of Students from Emergency Institutions*

In the fall of 1945 approximately 73,000 students were enrolled in the engineering colleges of the United States.† In the fall of 1946 enrollments had increased to more than 225,000. At that time fifteen institutions enrolled more students than had all the engineering schools of the country the year before. The Compton Committee report of 1946 refers to a recent survey which stated the estimated capacity of the engineering schools of the United States to be 155,000 students. Thus in a single year engineering enrollments had more than trebled and now exceed estimated maximum capacity by nearly fifty per cent. Data gathered by the Committee which submits the present report indicate that engineering schools of the United States are expecting to admit approximately 85,000 new students—freshmen, upperclassmen, and postgraduates—during the academic year 1947–48, and that their total enrollments of all students, new and old, may be approximately 250,000. Because of the growth of interest in scientific and technical pursuits one student out of every nine students of the country, including both men and women, is now enrolled in engineering (not including related fields of physical science), and no abatement of this trend is in immediate prospect. Thus it seems clear that a rapid rate of increase of enrollments will continue during the coming year and that the resources of engineering schools, already seriously overtaxed, will be loaded still further.

In spite of most strenuous efforts by all concerned to provide to the greatest possible degree to meet these demands, a great many students who desire to study engineering have been unable to gain admission to regular engineering colleges and have been forced to enter a variety of other types of institutions. Most of these students will seek admission to engineering colleges later. At the same time young men still in military service, including both those who have and those who have not previously attended college, will seek admission upon their return. Unless some form of military training law is enacted which will call students directly from high school to training camps, another wave of students just graduated from high school will add itself to the waves of applicants and students now in college.

The total situation that confronts engineering colleges is, therefore, indeed a complex and difficult one, the most difficult, perhaps, of that of any important group of institutions. One phase of this general situation is that which relates to the admission of students by transfer from the several types of insti-

* Presented at the 55th Annual Meeting, A.S.E.E. (Administrative Council), University of Minnesota, June 17–21, 1947.

† In 1941–42, the last year of normal "prewar" enrollments, the total number of engineering students in the United States was approximately 115,000.

tutions in which they are now enrolled for their earlier years. The Executive Committee of the Engineering College Administrative Council requested our Committee to review this situation, to appraise the magnitude and nature of the problems involved, and to recommend policies and practices in relation to them. This we do in the report that follows.

Early in our Committee's discussion two points became clear:

1. It was not desirable to confine attention to special new colleges established during the present emergency chiefly to accommodate veterans. Problems incident to the transfer of students from such institutions to engineering schools seemed not to differ essentially from those incident to transfer from regularly established colleges that do not customarily admit pre-engineers, nor from those arising from the transfer from all types of "feeder" institutions that have now greatly expanded their enrollment. We have therefore included in our considerations students now enrolled in the following types of institutions:

(*a*) Off-campus branches of the parent institution.
(*b*) Institutions to which students, enrolled in the parent institution, have been "farmed out" for their first year or, perhaps, first two years.
(*c*) Colleges of various types—liberal arts, teachers' colleges, women's colleges, etc.—many of which do not customarily admit pre-engineers.
(*d*) Junior colleges which may or may not previously have admitted pre-engineers.
(*e*) "Emergency colleges" established with the specific purpose of providing, temporarily, educational opportunities for those unable to gain admission elsewhere.

2. It appeared to be impracticable accurately to determine the total number of students in the entire country who may seek to gain admission by transfer to engineering colleges this fall. We are able to present some territorial samples and to hazard an estimate of total demand, and we have gained a reasonably clear conception of the more important aspects of the conditions—such as the extent of freshman-year preparation—that surround the admission and adjustment of transfer students to engineering college programs.

In particular, it has become abundantly clear that the capacity of engineering colleges to admit all applicants will be far short of the demand no matter what expedients might be adopted to provide for them.

Magnitude of the Problem

We present first a comparative summary of enrollment statistics for 1946–47 and estimated total capacities to receive students in 1947–48, based on responses from 108 engineering colleges in all parts of the country. The same institutions are included in the two sets of figures. Estimated capacities to admit new students are given in columns (7), (8), (9), and (11). Figures in column (2) should not be compared with those in column (7), since the latter do not include any freshmen carried over from last year, as in institutions that admit students at mid-years. Prospective percentage increases in total enrollment of undergraduates and postgraduates and of all students are given in columns (10), (12), and (13).

TABLE I

1946–47

1	2	3	4	5	6
No. of Colleges	Freshmen	Soph. Jr. Sr.	Total Undergr's.	Post-gr's.	Total Stud's.
108	72,110	91,522	163,632	12,705	176,337

1947–48

7	8	9	10	11	12	13
New Freshmen	New Soph. Jr. Sr.	Total New Undergr's.	Total Undergr's.	New Postgr's.	Total Postgr's.	Total Stud's.
47,437	13,306	60,743	183,809	5,160	13,726	197,535
Increase, 1946–47 to 1947–48			12.3%		7.5%	12.0%

By extrapolation based on the ratio of total students from 1946–47 in the above tabulation to the total of those tabulated in the JOURNAL OF ENGINEERING EDUCATION for January 1947,* a rough estimate of total enrollment for 1947–48 would be as follows:

TABLE II

Undergraduates	236,500
Postgraduates	16,000
Total, Undergraduates and Postgraduates	252,500

By similar extrapolation, the number of new students to be admitted in 1947–48 is estimated roughly to be:

TABLE III

New Freshmen	61,000
New Sophomores, Junior, and Seniors	17,200
New Postgraduates	6,000
Total New Students	84,200

* These statistics have been adjusted for apparent duplication of veteran enrollments in some institutions and for omission of statistics from other institutions.

These latter figures may be taken as the approximate capacity of the engineering colleges, with existing facilities, to admit new students during 1947–48. They may be compared with the total increase of 137,000 students (210,000–73,000) between the fall of 1945 and the fall of 1946. This will give some concrete conception—though an incomplete one—of the extent to which prospective engineering students who seek admission are being dammed back.

Students Seeking Admission. Sampling surveys of colleges of liberal arts, junior colleges, and one emergency college, in California, Pennsylvania, and eleven mid-western states, enrolling in all 160,279 students, indicated that 15,495 of these students desire to transfer to engineering colleges, a ratio of 9.7 per cent.* If this ratio holds for the

* This ratio varies widely in different types of institutions and, apparently to some extent, in different sections of the country. Our Committee's studies show a range from 3.9 per cent in liberal arts colleges in Ohio to 12.8 per cent in junior colleges in California.

total national enrollment of approximately 930,000 students † in similar institutions, the total number seeking admission to engineering in advanced standing is approximately 90,000. (This figure is perhaps unduly weighted by enrollments in California Junior Colleges.) This society's Committee on Manpower estimates this number to be approximately 55,000 freshmen and 22,000 members of other classes, mostly sophomores. These students will doubtless not all desire to transfer in one year. However, the comparison of the total number comprising this group with 17,200, the number of new sophomores, juniors, and seniors which our Committee estimates the engineering colleges can receive next year, is significant of the general situation surrounding engineering education to which reference has already been made. Most institutions will give priority to their own returning ex-servicemen in filling these 17,200 vacancies. It seems unlikely that a large fraction of the 80,000 or more students now enrolled in other types of institutions awaiting transfer will gain admission to engineering colleges either this year or next year.

THE NATURE OF THE PROBLEM

Part of the problem that will confront engineering colleges this fall arises from the number and variety of types of institutions in which transferring students have been enrolled. However, they seem not to promise any more or as much difficulty either in the nature of the problems or in number of students affected as have those incident to the re-adjustment of former students of the Army Specialized Training Program with which we have become familiar in the past year.

† See "Study of Pre-Engineering Enrollment in Colleges and Universities (as of November, 1946)," by Henry H. Armsby, U. S. Office of Education.

The principal types of institutions in which students awaiting transfer have been enrolled have already been named. Remarks about each type, condensed from a considerable volume of material, may be of some interest and value.

State Sponsored Emergency Colleges. The state education departments of Massachusetts, New York, Pennsylvania, and North Carolina have sponsored and supported the organization of special emergency, and presumably temporary, institutions as follows:

- Fort Devens College, Massachusetts.
- Champlain, Mohawk, and Sampson Colleges, New York.
- The so-called "Area College Centers," ten in number in Pennsylvania under the direct supervision of the State Department of Public Instruction, and seven additional area or "Credit" centers administered by The Pennsylvania State College in cooperation with the State Department of Public Instruction.
- Twelve centers of instruction in North Carolina.
- Farragut College in Idaho, which is also of emergency type but is privately financed.

In Massachusetts, New York, and Idaho the institutions are located on military reservations. In Pennsylvania and North Carolina classes are conducted during the late afternoon or evening hours in high school buildings. Boards of trustees of the institutions are for the most part comprised of presidents of institutions of the state or vicinity. Equipment for science courses, meager at the start, is now being accumulated more adequately. In some states, faculties are comprised of experi-

enced college teachers; in others, high school teachers are employed. In Pennsylvania the proportion of college teachers in the various area colleges ranges from 100 per cent to zero. All teachers appear to be carefully chosen, drilled, and supervised and their morale and effectiveness have been commented on favorably by members of the Committee who visited the institutions and observed their work. Admission requirements are much the same as in many publicly supported institutions though rather more liberal, both in statement and in application. Requirements in mathematics are somewhat light, but with few exceptions, entering students offer more than minimum requirements. Curriculum requirements are about the same as in regular engineering schools, except for fewer total required credits, the following examples being typical:

Freshman year, each semester:

Mathematics—semester credit hours	5
Chemistry	4½
Drawing and descriptive geometry	4
English	3
Total	16½

Freshman and sophomore years, total credits for four semesters:

Mathematics—semester credit hours	16
Chemistry	10
Physics	8
Drawing and descriptive geometry	6
English	8
Total	48

In New York and Pennsylvania more than one-third of the students in emergency colleges were enrolled in engineering.

While most of these institutions were for the most part originally established to offer work of the freshman year only, the pressures upon them are such that steps are being initiated to extend their programs to two years, and at least one institution has announced the hope of becoming permanent. If students continue in them for more than two semesters the problems of senior engineering schools to provide programs such that they can complete normal degree requirements in a total of eight semesters are likely to be very difficult. Summer session adjustment programs may be necessary for such students.

Liberal Arts, Teachers', Women's, and other Types of Colleges. These institutions in the aggregate enroll a good many students hoping to transfer to engineering. It is from these instituions, many of which have little or no prior experience with pre-engineers, that perhaps the greatest variety of problems will arise. The institutions vary within wide limits of quality, up to the highest ranks of academic excellence—as with certain of the women's colleges. Standards of admission also vary: in some instances where the admission of male veterans has been undertaken as a public service, admission standards have been relaxed as compared with those required of regular entrants. Curricula also vary widely, from those substantially the same as the usual engineering freshman year to some that differ in important respects. The following, for example, omits engineering drawing:

English—semester credits	6
Bible	3
History, economics, or other elective	3
Chemistry	6
Mathematics	6

Another example of admission requirements and pre-engineering curriculum provisions in twenty-four lib-

eral arts colleges in Kentucky, Indiana, Michigan, and Ohio follows:

Typical entrance requirements, in Carnegie units:

English	3
Foreign language	2
History	1
Laboratory science	1
Mathematics	2
Total specified	9
Total required	15

Curriculum provisions, freshman and sophomore years, in semester credit hours:

	Most Frequent	Min.	Max.
Chemistry	8	8	16
Physics	10	8	16
Mathematics	19	$15\frac{2}{3}$	28
Drawing	3	0	6
Descriptive geometry	3	0	5
English	6	0	12

Some of these curricula exemplify a particular point: semester credits in mathematics, in some instances, are limited to six for the freshman year. Yet an examination of the syllabi of the courses discloses that the work extends through analytical geometry, and acquaintance with the quality of the work of the institutions and a study of examination papers make it clear that students who pass the courses will have covered fully the work of the customary engineering requirements in trigonometry, college algebra, and analytical geometry. Male students taking certain of the courses were finding difficulty in keeping up with the women students. The point to be observed appears to be that evaluation based on credits awarded in the feeder institutions may be misleading, either one way or the other: over-evaluation or under-evaluation. Placement tests in mathematics and science may be a more accurate way to appraise the preparation of students transferring from this group of institutions.

Junior Colleges. The situation as to transfer from junior colleges differs from previous experience chiefly as to the numbers of students involved and the fact that some engineering colleges are likely to admit such students in significant numbers for the first time. In this connection it may be appropriate to remark that the present emergency is tending to accelerate the trend toward enrollment of students in the thirteenth and fourteenth (junior college) grades of public school systems and thus greatly, and perhaps permanently, to increase the number of students seeking admission to the junior year of engineering colleges.

Off-Campus Branches of the Parent Institution. No phase of the present emergency is more interesting than the establishment of branches of the main institution. As examples, Illinois has branches at the Navy Pier, Chicago, enrolling 2,500 freshmen, a branch at Galesburg, enrolling 1,000 freshmen, and "Centers" in more than thirty high schools. The numbers of pre-engineers at these branches in 1946–47 were, respectively: 1,300, 100, and 1,000 (650 of whom are headed for the University's campus). Wisconsin has thirty-four extension centers enrolling 5,500 students, including pre-engineers. Iowa State College and Georgia School of Technology have overflow groups at nearby military camps and transport faculty or students or both back and forth from campus to camp for special purposes, such as instruction by teachers or laboratory work by students. Other uni-

versities have also established branches, but the details of their operation are not known to our Committee. The Pennsylvania State College has "farmed out" its first-year students as follows: to its own four "undergraduate centers," or junior colleges, to its school of forestry, to thirteen state teachers colleges, and to four cooperating privately endowed colleges, where its 3,000 freshmen, including 1,000 engineers, are enrolled. In these instances the regular freshman engineering curricula are in effect, and the work is coordinated by the parent institution. Curricular problems of transfer will not be difficult. Placement examinations in English and mathematics are proposed as means of determining whether special adjustments will be needed in subject matter or to upgrade students.

A similar process of farming out students has been adopted by Alabama Polytechnic Institute and the University of Alabama which have 1,000 students enrolled in "basic curricula" of the freshman and sophomore years in twelve cooperating institutions. There is no guarantee of admission to the parent institution at the end of the two-year period.

Summary

The most significant condition that confronts the colleges of engineering is the sheer weight of numbers. The necessity of providing special adjustment programs for students transferring in advanced standing tends to augment difficulties caused by overcrowded enrollments by imposing additional scheduling and adjustment problems on heavily burdened teaching and administrative staffs. More than the normal number of hours of the academic day, the teaching of abnormally large classes and the accompanying load of problem correction, working under the strain of attempting to maintain proper standards of instruction, often under very difficult conditions—all of these add to the difficulties of operating engineering colleges. In short, conditions are without precedent.

In most instances the campus work of engineering schools is being done in very little space in addition to that available in pre-war years. In a majority of institutions it has not been possible to increase faculties in proportion to the increase in students. Budgets have lagged far behind enrollments. And over everything hangs the uneasiness that results from not being able to provide for the tens of thousands of worthy applicants who cannot be admitted.

Of course, there are brighter sides of the picture. Chief of these is the high quality of our students and the purposefulness of their work. Never before have we had such an able, courteous, or responsive group of students to work with; and that serves greatly to ease all our difficulties. Another is the boon of increased research activities; which also helps to maintain our morale. Finally, there is the stimulus which comes from the increase in graduate work. Somehow, in spite of the compounding of burdens, we are managing, collectively, to progress in both these latter directions. And this is vital to the welfare and progress of engineering education.

Our Committee has discussed these matters with a view to selecting those aspects of the problems on which recommendations may be laid before you.

We recommend as follows:

1. That while colleges should operate as nearly as possible at full capacity, they should not admit more stu-

dents than can be taught effectively. On the average, it seems probable that the maximum number that can be admitted under this condition will be reached in 1947–48.

We base this recommendation on the fundamental belief that the one fault that should be avoided at all costs is the providing of substandard education, especially for students preparing for professional careers.

2. That facilities and staffs be devoted to as great an extent as feasible to upperclassmen and graduate students. Since there is a large surplus of applicants for admission in advanced standing, preference may be given to such applicants over freshmen. Suitable safeguards should be established to control the quality of students admitted in advanced standing.

3. That educational facilities be reserved for the better qualified students at all levels.

4. That preference in granting admission be given to students who have removed important irregularities of schedules. In cases where students must be admitted with such irregularities, they should be required to make them up as promptly as possible, particularly in summer sessions.

5. In the interest of faculty health and effectiveness, where it has not already been done, that the three-semester or four-term academic year be abandoned at once in favor of the customary two-semester or three-term year, with summer sessions serving only as adjustment periods and not for acceleration.

6. That achievement and/or aptitude tests be given in key subjects: mathematics, physics, chemistry, and English, to students admitted in advanced standing, and that subsequent classes in these subjects or in subjects involving their use be sectioned on the basis of preparation and ability.

7. That this Society take prompt steps to set up an agency for the exchange of teachers.

8. That research and postgraduate work be fully maintained because of the necessity of producing as promptly as possible an adequate supply of recruits for teaching and research staffs.

9. That the former practice of state and municipally supported institutions of admitting students from outside of their states or municipalities be restored as soon as feasible.

Respectfully submitted,

Ray Palmer Baker
H. W. Barlow
L. M. K. Boelter
J. F. Buchanan
C. L. Emerson
Frank Kerekes
H. E. Nold
H. P. Hammond, *Chairman*

Report on Present-Day Salaries of Members of the Instruction Staffs of Engineering Schools in United States and Canada*

Foreword

The object of this report is to meet the request of the Administrative Council of the American Society for Engineering Education to make a survey of the staff compensation in the engineering colleges and to give the results thereof, with the supplementary idea of comparing the current compensation with the data on salaries given in the report on "Present Status and Trends in Engineering Education in the United States," which was prepared by the signer of this report and published in 1939 by the ECPD. The present report, which was proposed by the Executive Committee of the Engineering College Administrative Council, is under the direction of the President and Secretary of the Council. Dr. Killian requested the signer of this report to supervise the collection of the data and its analysis and publication, and assigned Mr. M. G. Kispert to assist in the matter. Colonel D. C. Jackson, Jr., who directed the analysis of the material for the 1939 Status and Trends report agreed to participate.

Therefore a questionnaire was prepared to send out to all engineering schools in the United States and Canada inquiring regarding the salaries of the different ranks in the staffs and the conditions of their employment. Its form corresponded with the form used for obtaining this particular information by the ECPD Committee on Engineering Schools in the 1930's. This makes the data in the present report comparable with those on salaries and conditions of work in the 1939 Status and Trends report, which referred more particularly to the years 1934–36. Thus a comparison of the two reports shows the changes in salaries after a period of substantially ten years.

The interest exhibited in this matter is shown to be very notable, because within 36 days of their mailing 148 completed questionnaires had been returned, which was 92.5% of the total number sent out.

Colonel Jackson, Mr. Kispert and I all agree in the interpretations and conclusions given throughout this report, and the interpretations therefore are founded on a large variety of successful experience.

Dugald C. Jackson

Introductory

During the period when the Committee on Engineering Schools of the Engineers' Council for Professional Development was carrying forward its

* Presented at the 55th Annual Meeting A.S.E.E. (Administrative Council), at the University of Minnesota, June 17-21, 1947.

original program of accrediting engineering curricula, the salary level of engineering faculties was generally rather low. Indeed it was sufficiently low to warrant concern that ultimately it would be a deterrent to the continued advance of engineering education, which is essential to industrial progress and the welfare of the nation. Two quotations from the ECPD 1939 report on "Present Status and Trends of Engineering Education in the United States" (hereinafter referred to as the 1939 report) will highlight this point.

> "Salaries, extent of conventional teaching loads, and facilities provided for the teaching, stand about stationary except in some notable institutions." (Page 142)
>
> ". . . the continuing low level of engineering school salaries in so many of the institutions" (compared with industrial salaries) "undoubtedly affects the distinction of the faculties, since many men of fine qualifications for faculty positions, and tastes which would lead them in that direction, have obligations which press them toward industrial employment rather than entering low-salaried positions in faculties of engineering schools with inadequate financial suport. Many such engineering schools are distant from the centers of great population and large engineering activity, so that inadequate salaries in such locations tend to isolate the teachers from contact with important engineering activities and also prevent resonably frequent attendance on the stimulating meetings of professional engineering societies." (Page 79)

The average of salaries had remained at a low level since the report of the SPEE Board of its study of 1923 to 1929 which was published in 1930 and 1934.

If these statements were true in 1939 at the end of the depression of the 1930's, it is even more important at the present time for the benefit, not merely of engineering education but of the entire profession of engineering and even of the nation itself, that considerable upward revision of engineering school salaries be brought to pass. This is because of the sizeable increases in cost of living and in salaries paid by industry to engineers. This report therefore provides information as to whether engineering schools generally have maintained the level of their faculty salaries commensurate with the increase of cost of living.

Treatment of Gathered Material

For convenience in comparison, the engineering schools utilized in this 1947 report are grouped successively in Geographical Regions and Types of Institutions in the same manner as in the 1939 report. In the 1939 report the effectiveness of institutions was tested by grouping them according to the proportion of the curricula in the program of each institution which had been accredited at that time by the Engineers' Council for Professional Development. We are here dealing with adequacy of salaries compared with cost of living, and the grouping according to accrediting has not been made for the present report. However, a general comparison between salaries and accredited standing is herein made.

Regions I to VII in the present report correspond directly to the seven Geographical Regions in the 1939 report and are as follows: Region I: New England States. Region II: Middle Atlantic States. Region III: North Central States. Region IV: South Eastern States. Region V: South Central States. Region VI: South Western States. Region VII: North Western States. The detailed listing of the states and the District of Columbia in

these seven regions is given in Appendix A, pages 153 and 154, of the 1939 report. In this present 1947 report, Region VIII has been added to include the engineering schools in Canada, Alaska, and Hawaii, which were not included in the 1939 report because the Committee on Engineering Schools of ECPD did not have them on its accrediting list.

In both reports eight type groups are used in accordance with the types of the institutions in which engineering instruction is given. This was determined jointly by the scope and the major source of support of each institution. These types are not separated by sharp lines of demarcation but nonetheless are classed rather readily into the following eight groups:

Privately Endowed Universities
State Universities
Municipal Universities
Privately Endowed Polytechnic Institutes
State Polytechnic Institutes
State Colleges of Engineering and Agriculture
Privately Endowed Colleges
Military Colleges

The military colleges include both those privately endowed and those supported by state or federal funds. A more detailed explanation of these groups is given on page 74 of the 1939 report.

The 1939 report was concerned only with engineering schools within the continental limits of the United States, which accounts for the use of the word "state" in connection with universities, polytechnic institutes, and colleges of engineering and agriculture to designate institutions whose government is under the controls of state legislatures and whose finances to a large extent come from legislative appropriations of state tax funds. Institutions similarly governed and supported but located in United States territories or in the provinces of Canada are included in the 1947 report. Hence the term "state" in this latter report includes all of such institutions whether in the United States, its territories, or Canada, and also at least one institution which is supported by federal funds.

The table below gives the numerical distribution of engineering schools both by geographical regions and by types of institutions for the 1939 and 1947 reports.

Regions	1939 Report	1947 Report	Types of Institutions	1939 Report	1947 Report
I	13	15	Endowed Universities	24	26
II	32	29	State Universities	37	45
III	25	24	Municipal Universities	6	6
IV	21	21	Endowed Polytechnic Institutes	14	16
V	16	16	State Polytechnic Institutes	8	12
VI	15	16	State Colleges of Eng'g. and Agri.	20	19
VII	11	12	Endowed Colleges	15	15
VIII	—	10	Military Colleges	4	4
	133	143		128	143

Note: The 1939 report dealt only with those institutions that had been visited in connection with accrediting.

Out of 135 institutions visited by the Committee on Engineering Schools and of which the curricula were acted upon by October, 1938, one was omitted from the tables because of inadequate information and one had withdrawn from engineering work prior to the 1939 report. The salary charts by regions therefore as of that date deal with 133 institutions. The data in the questionnaires of five institutions were not available for classification by types, which caused the number of institutions in these charts and tables to be reduced to 128. For the 1947 report, questionnaires were received from 148 institutions. Unfortunately, in five cases the questionnaires arrived after the analyses were well under way or the information proved inadequate. Thus the data from 143 engineering schools were used in preparing the tables and charts in this report.

The 1947 data have produced two tables and eleven charts, as compared with one table and five charts on salaries in the 1939 report. In the latter, Chart 5 contains data for two academic ranks. In order that the results may be comparable, the same basic approach has been used in the present report as in the 1939 report. For each of the four faculty ranks (Instructor, Assistant Professor, Associate Professor, Professor) the following are shown: medians of maximum, average, and minimum values of the salaries. The data on Department Heads, which include Chairmen of Departments, have been incorporated with the data on the academic ranks which the individuals hold. The 1947 report also supplies similar information for Department Heads separate from the regular faculty, which was not separated in the 1939 report.

The additional table in this report gives the salaries by geographical regions for the four academic ranks and also separately for the Department Heads. The additional charts in this report show the salaries geographically as follows: By regions—Chart 3, Associate Professors; Chart 7, Instructors; Chart 9, Department Heads; for the ten highest paying engineering schools—Chart 11, Department Heads and the four academic ranks. In this last chart the selection of the ten highest paying institutions was based upon the average salaries of Professors, and therefore they are not necessarily the ten highest paying institutions in the other ranks.

The 1947 salary figures are on the academic-year basis, which is assumed to be about nine calendar months. The information in the questionnaires indicated that to a large extent additional salary is paid for summer teaching, approximately 33⅓ per cent of the salaries for the academic year of nine months for Instructors and Assistant Professors, and 25 per cent of the nine-month salary for Associate Professors and Professors. In view of this fact it was decided to reduce the reported twelve-month salaries (reported by 25 institutions), except those of Department Heads, to a nine-month basis in accordance with the foregoing increases for summer work. Since Department Heads give substantially twelve months' service, regardless of how the salaries are paid, the full amounts of those salaries as reported by the institutions are used in this report when developing medians for Department Heads only, but those salaries were reduced to the nine-month basis when incorporated with salaries of Professors.

Because the 1939 report was based on information gathered by the Committee on Engineering Schools for a

more general objective, the data available at that time were not always susceptible to a reduction to an academic-year basis. Thus some of the salary figures utilized in preparing the tables and charts for that report were for twelve months, although the vast quantity of them were for the academic year. However, even a cursory viewing of the charts in the two tables will show that this does not interfere with the indication of trends in salaries nor invalidate the conclusions drawn from the 1947 data.

Between the gathering of the data for the two reports, three changes have occurred in the organizations or activities of institutions included in the 1939 report, which affect their treatment in the 1947 report. The most drastic of these changes is probably the amalgamation of an endowed college with an endowed polytechnic institute into an enlarged endowed polytechnic institute of greater scope. The other changes have caused two institutions to be shifted between groups in the analysis of data according to types of institutions; from endowed college to endowed university, and endowed college to state university, on account of a shift in a major portion of financial support or of enlargement of university-type activities.

The great bulk of the staff compensation in the engineering schools consists of salaries for instructional duties and research activities directly connected with the educational programs of the institutions. However the engineering schools are conducting considerable research for industry and the government on a contract basis, and for this frequently utilize the part-time services of members of their teaching staffs. This additional activity of engineering schools, related to but not part of their regular educational programs, raised the thought of developing information—

- On institutional policy for payment of supplementary compensation, and
- On procedures for paying staff members for work on contract research for industry or government.

A consideration of the complexities involved and the time required to obtain the information, which would be reasonably complete and comparable between institutions, showed that an adequate study could not be completed in time for presentation to the Administrative Council at the 1947 annual meeting of ASEE. Therefore it was deemed better to incorporate such a study in the survey to be made of the salaries of staffs of other kinds of professional schools and of engineers in industry.

Discussion of Charts and Tables

Charts 1, 3, 5, 7, and 9 relate to salaries respectively of Professcrs, Associate Professors, Assistant Professors, Instructors, and Department Heads separately given, shown according to the first seven of the Geographical Regions. Data for Region VIII salaries are given in Table 1, but are not shown graphically in the charts by regions. Charts 1 and 5 are comparable respectively to Charts 1 and 2 of the 1939 report.

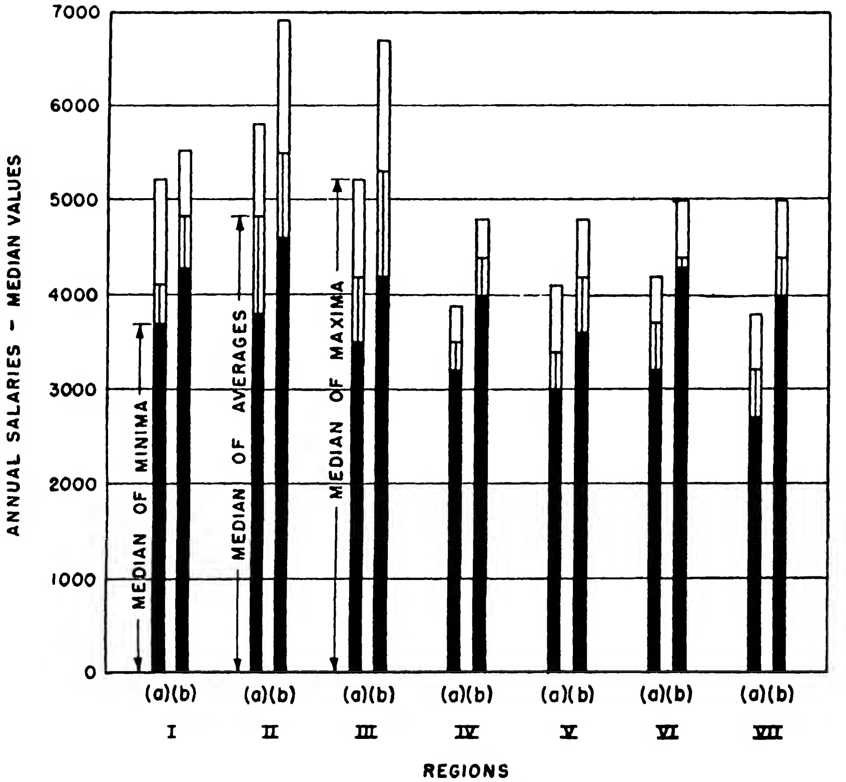
The pattern of salary variation from Region I to Region VIII in 1947 is similar in all five ranks, including the Department Heads, and this is the same general pattern as appeared in the 1939 report for the first seven regions, based upon the salaries in the middle 1930's. Thus the following statement, which was made on page 76 of the 1939 report, holds true also for the 1947 infor-

CHART I. ANNUAL SALARIES OF FACULTY MEMBERS

PROFESSORS
INCLUDING DEPARTMENT HEADS

Engineering Schools Arranged by Geographical Regions

Median Values of Maximum, Average, and Minimum Salaries



(a) Salaries based on ECPD Report on Engineering Education published in 1939

(b) 1946-47 salaries

mation: "Regions I, II, III cover areas of population and industrial density, and generally speaking of relatively high cost of living, and in these regions the salaries are notably higher than in the others."

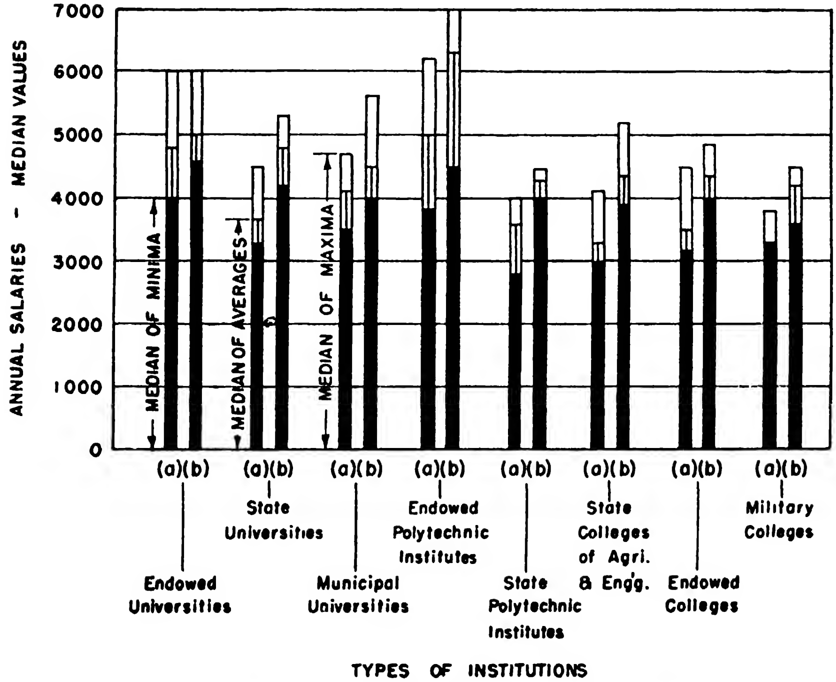
Table 1 contains the information upon which the charts just discussed are based. The graphical form has been used for the presentation of the information on the separate ranks since it more readily shows the variation of salaries between general geographical regions and that the pattern holds true regardless of rank. However, this method does not give an overall composite picture of conditions throughout the nation, and Table 1 was developed

CHART 2. ANNUAL SALARIES OF FACULTY MEMBERS

PROFESSORS
INCLUDING DEPARTMENT HEADS

Engineering Schools Arranged by Types of Institutions

Median Values of Maximum, Average, and Minimum Salaries



(a) Salaries based on ECPD Report on Engineering Education published in 1939

(b) 1946-47 salaries

to provide this general view. This manner of treatment of data is utilized also in the case of the groupings by types of institutions.

Charts 2, 4, 6, 8, 10 of this report give information corresponding respectively to Charts 1, 3, 5, 7, 9 of the report except that the grouping of the results is according to the types of institutions instead of according to geographical regions and the data for the institutions in Canada, Alaska, and Hawaii are included. The relation of the charts in the 1947 and 1939 reports, for comparative purposes, is as follows:

1947 Chart 2	with 1939 Chart 3
1947 Chart 4	with 1939 Chart 4
1947 Charts 6 and 8	with 1939 Chart 5

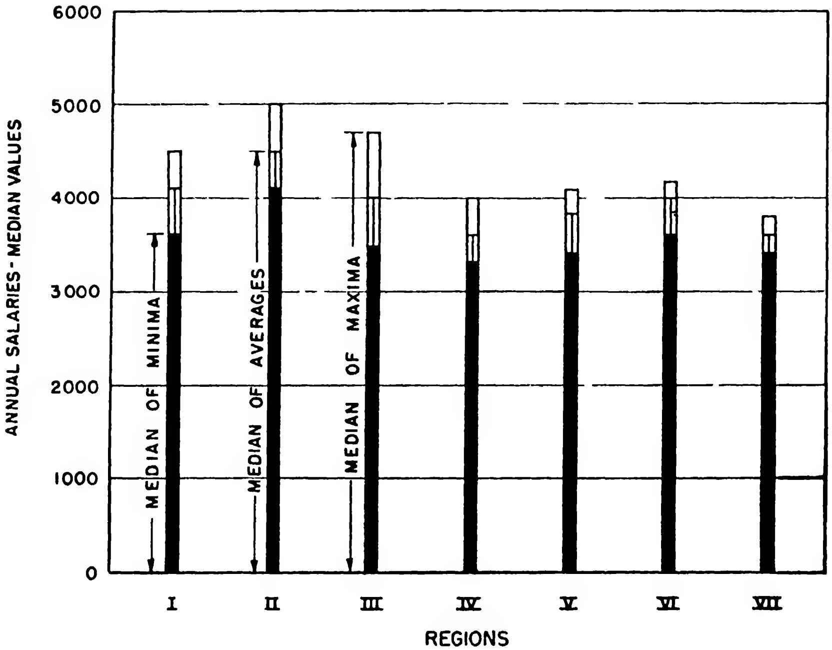
First giving specific attention to the salaries of Associate Professors and Instructors both for the middle of the depression of the 1930's and for the immediate post-war period, a compari-

CHART 3 ANNUAL SALARIES OF FACULTY MEMBERS

ASSOCIATE PROFESSORS

Engineering Schools Arranged by Geographical Regions

Median Values of Maximum, Average and Minimum 1946-47 Salaries



son of the corresponding charts shows, between the two periods, that the average increase in salaries of Associate Professors approximates $900 and of Instructors is about $700. It is to be noted that these values are substantially the same as the increase for Assistant Professors and Professors as developed in the discussion of the regional charts. For Associate Professors the greatest increase in the median of average salaries ($1,200) was made by the State Colleges of Engineering and Agriculture and the smallest increase in average salaries ($700) occurred in the Municipal Universities. Similarly, for Instructors the maximum and minimum increases in medians of average salaries between the 1939 report and the 1947 report are respectively $900 by the State Colleges of Engineering and Agriculture and $400 by the State Polytechnic Institutes.

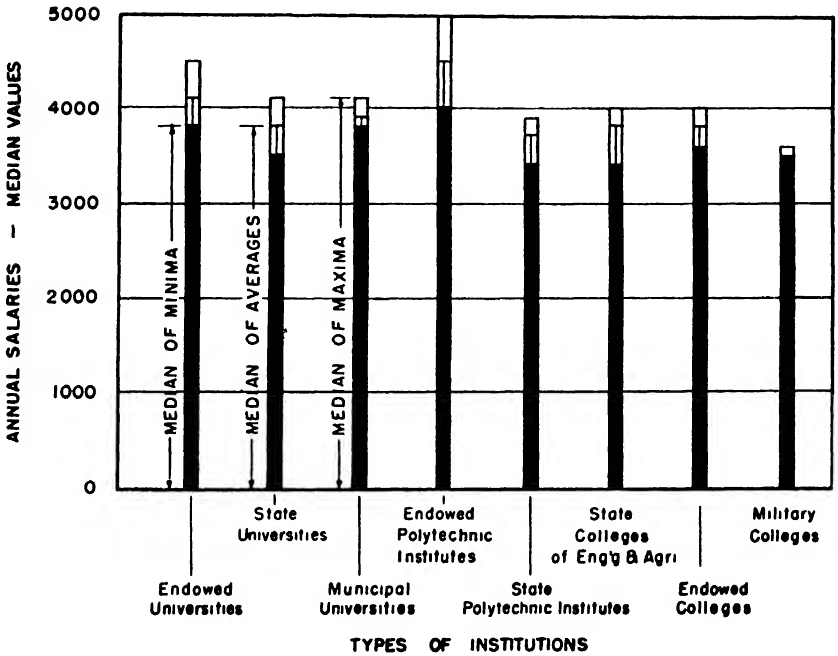
There is not as consistent a pattern from rank to rank when engineering schools are arranged by types of institutions as in the regional grouping. However, the 1939 report shows that the Endowed Polytechnic Institutes and the Endowed Universities had the highest average salaries for the three upper ranks, with the Municipal Universities standing in third place in each case. For Instructors, the Municipal Uni-

CHART 4. ANNUAL SALARIES OF FACULTY MEMBERS

ASSOCIATE PROFESSORS

Engineering Schools Arranged by Types of Institutions

Median Values of Maximum, Average, and Minimum 1946-47 Salaries



versities granted the highest average salaries, with the other two groups following in a tie for second place. The medians of average salaries of all four ranks are definitely lower in the other five types of institutions.

In 1946–47 the pattern of salary variation between types of institutions, for medians of average salaries, is rather similar to that in 1939. However, the State Universities have overtaken the Municipal Universities during the decade between the gathering of the data.

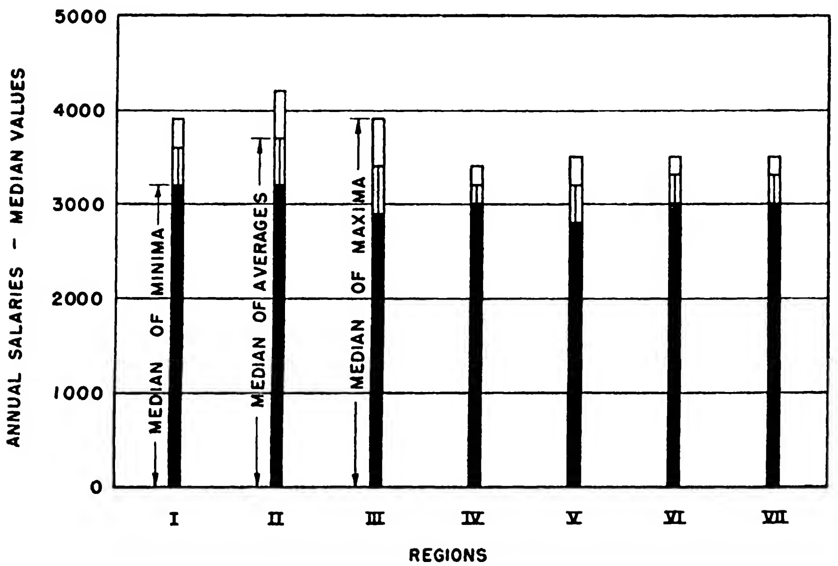
The apparent gain by the lower paying types of institutions in the average salaries of the lower ranks is salutary. However, it seems to be partly because the higher paying types of institutions have not had relatively as large an increase in average salaries. It is rather serious that the overall median of average salaries of Associate Professors in all types of institutions is less than $4,000, of Assistant Professors is less than $3,400, and of Instructors is less than $2,600. These can hardly be considered as satisfactory base incomes (even though for the academic year only) for professional men with the experience and competency required for the specific ranks. The situation is even more serious when the overall medians

CHART 5. ANNUAL SALARIES OF FACULTY MEMBERS

ASSISTANT PROFESSORS

Engineering Schools Arranged by Geographical Regions

Median Values of Maximum, Average, and Minimum 1946-47 Salaries



of minimum salaries for each rank are considered, especially in view of the large increase in the cost of living.

Chart 10, dealing with the salaries of Department Heads, shows a similar pattern of salary variation, except for medians of averages at Endowed and State Universities. This last is possibly owing to the fact that in many of these universities there is no permanent head or chairman of the department; the department chairmanship is without additional compensation for the administrative duties, being rotated among the members of the department, sometimes even without regard to academic rank. In considering the salaries of Department Heads, it is worthy of note that the medians of average salaries for Regions II and III, as shown in Chart 9 and Table 2, are much greater than for the other six regions.

Engineering school salaries still are higher in the regions where the greater proportion of the total number of institutions are fully or nearly fully accredited. Since the original accrediting program, there have been about the same number of improvements in accrediting in Regions I, II, and III together as there have been in Regions IV, V, VI, and VII combined. Therefore the following statement in the 1939 report still appears to be true:

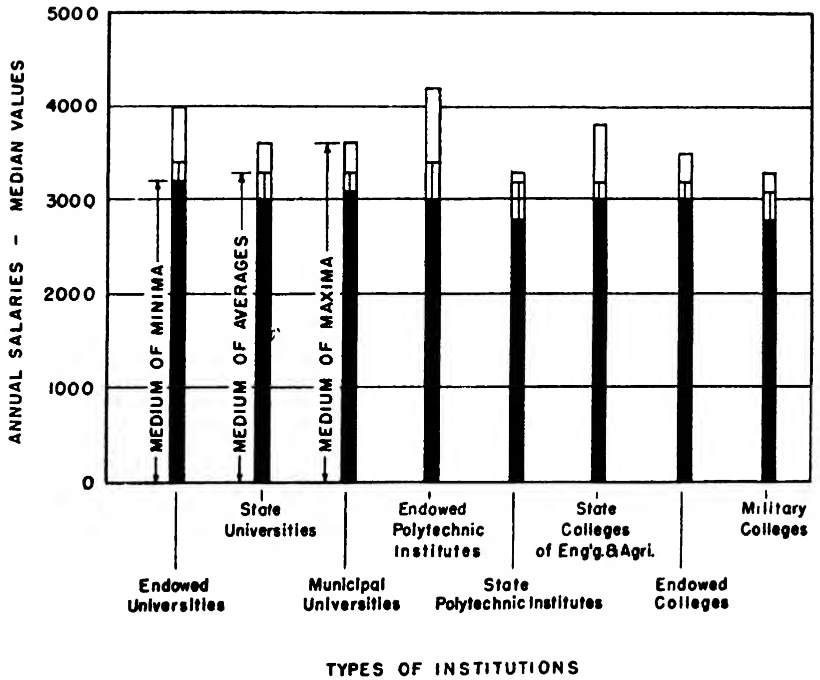
"Since the engineering schools which have a high proportion of their curricula accredited . . . are, in general, those in

CHART 6. ANNUAL SALARIES OF FACULTY MEMBERS

ASSISTANT PROFESSORS

Engineering Schools Arranged by Types of Institutions

Median Values of Maximum, Average, and Minimum 1946-47 Salaries



which the higher salaries are paid in the several teaching ranks, this relation probably is significant. The correlation may come about through the higher salaries enabling these institutions to secure abler engineers and scientists, as well as abler men in the other branches, for all ranks of their teachers. Even though the salaries in the lowest ranks may not be of the highest level, the stimulating influence of opportunity is there—regarding ultimate salary, recognition of creative work, and personal appreciation as distinction is earned." (Page 82)

For the 143 engineering schools as a group, the 1947 data show that the average increase in salary for all ranks, over the salaries for the earlier dates, is approximately the same—less than $1,000. In view of the great increase in the cost of living since 1940, it is important that particular attention be given to the lower two ranks. These men must have adequate income for reasonably satisfactory support of their families without having to resort to activities of a "pot-boiling" character to supply the necessities of life and thereby divert their attention from maintaining their competency in their professional fields. However, since the dollarwise increase in average salaries

CHART 7. ANNUAL SALARIES OF FACULTY MEMBERS

INSTRUCTORS

Engineering Schools Arranged by Geographical Regions

Median Values of Maximum, Average, and Minimum 1946-47 Salaries

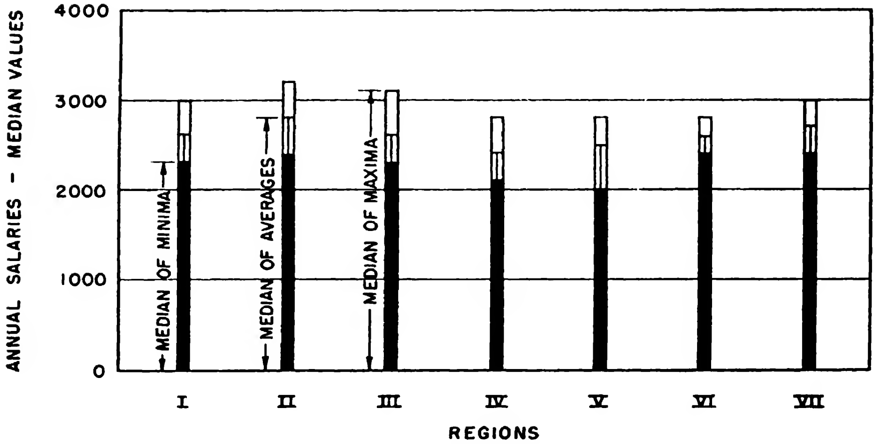


CHART 8. ANNUAL SALARIES OF FACULTY MEMBERS

INSTRUCTORS

Engineering Schools Arranged by Types of Institutions

Median Values of Maximum, Average, and Minimum 1946-47 Salaries

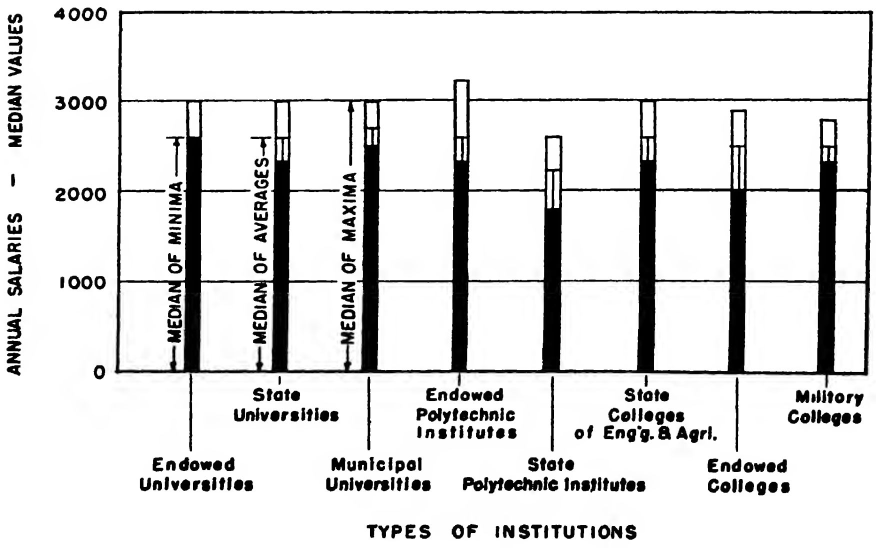
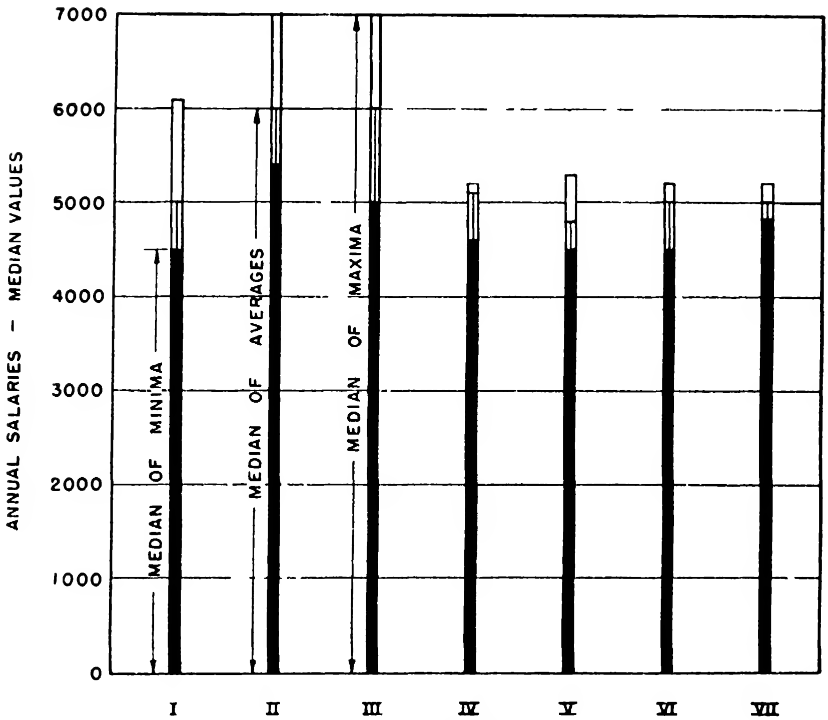


CHART 9. ANNUAL SALARIES OF FACULTY MEMBERS

DEPARTMENT HEADS

Engineering Schools Arranged by Geographical Regions

Median Values of Maximum, Average and Minimum 1946-47 Salaries



is substantially the same for all ranks, the differentials between Instructors' and Professors' salaries have been somewhat reduced. This gives even greater force in 1947 to the following statement made on page 79 of the 1939 report:

"It is reasonable to view with caution moderate levels of professors' salaries associated with relatively high minimum salaries in the lower ranks (as found for some institutions), as likely to gather ultimately into such teaching staffs the less creative and more mediocre types of men, there seeming to be only moderate ultimate levels of salary (and probably of achievement) to be reached in at least some of those institutions under their present conditions."

In general the medians of the average values of salaries in the charts are indicative of what the faculty members in each rank are receiving as compensation for their activities during an academic year. This does not include any income received in connection with a part-time consulting practice or from publications or special research work

TABLE 1

ANNUAL SALARIES OF FACULTY MEMBERS

Engineering Schools Arranged by Geographical Regions

Median Values of Maximum, Average, and Minimum Salaries

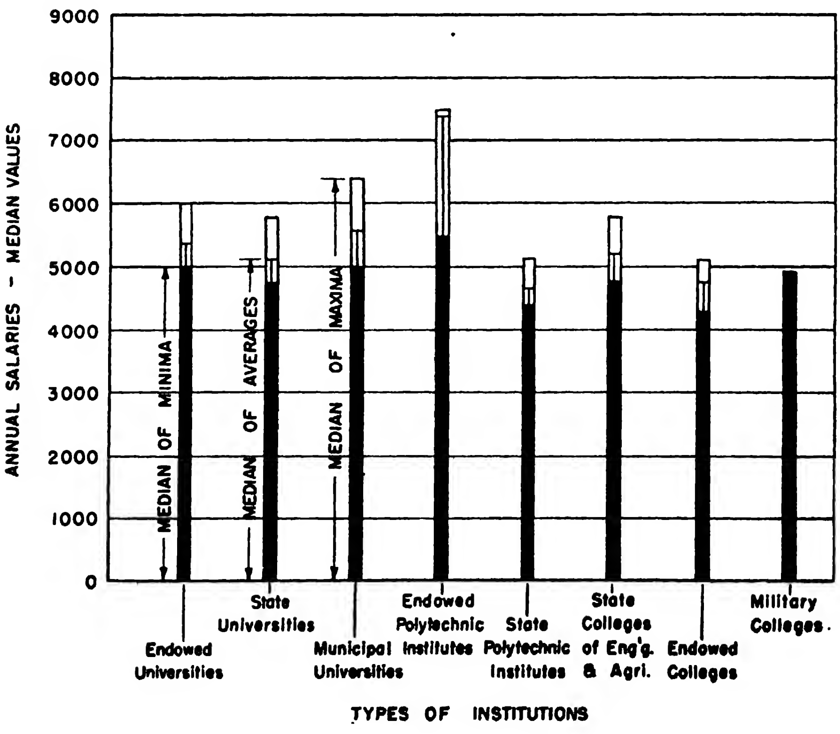
Region	No. of Institutions	Medians of Maxima					Medians of Averages					Medians of Minima				
		Dept. Head	Prof.	Assoc. Prof.	Ass't. Prof.	Instr.	Dept. Head	Prof.	Assoc. Prof.	Ass't. Prof.	Instr.	Dept. Head	Prof.	Assoc. Prof.	Ass't. Prof.	Instr.
I	15	6100	5500	4500	3900	3000	5000	4800	4100	3600	2600	4500	4300	3600	3200	2300
II	29	7000	6900	5000	4200	3200	6000	5500	4500	3700	2800	5400	4600	4100	3200	2400
III	24	7000	6700	4700	3900	3100	6000	5300	4000	3400	2600	5000	4200	3500	2900	2300
IV	21	5200	4800	4000	3400	2800	5100	4400	3600	3200	2400	4600	4000	3300	3000	2100
V	16	5300	4800	4100	3500	2800	4800	4300	3800	3200	2500	4500	3600	3400	2800	2000
VI	16	5200	5000	4200	3500	2800	5000	4400	4000	3300	2600	4500	4300	3600	3000	2400
VII	12	5200	5000	3800	3500	3000	5000	4400	3600	3300	2700	4800	4000	3400	3000	2400
VIII	10	6000	5600	4100	3400	2800	5300	4500	3800	3100	2500	4800	4500	3700	2800	2200

CHART 10. ANNUAL SALARIES OF FACULTY MEMBERS

DEPARTMENT HEADS

Engineering Schools Arranged by Types of Institutions

Median Values of Maximum, Average, and Minimum 1946-47 Salaries



for which pay may come during the academic year. Since most faculty members will be participating in one of these or teaching in perhaps 50 per cent of the summers and receiving additional salary for that, the salaries as stated in both the 1939 and the 1947 reports are a few hundred dollars less than the total earned income on the average for all four ranks of engineering faculties. However, the figures in the two reports are comparable since they are recorded on substantially the same basis.

The average percentage increases in the medians of average salaries between those paid during the middle 1930's (which is the period for the 1939 report) and those for 1946–47 are approximately as follows: Professors 20 per cent, Associate Professors 30 per cent, Assistant Professors 32 per cent, Instructors 36 per cent. Since these percentage changes and those discussed later in this section are computed from increases of *median* salaries, they are not likely to fit exactly the conditions at a particular engineering school. However the methods of computing the salary figures were similar for the 1939 and 1947 data. Therefore the computed percentage changes of median salaries are reasonably close approximations when considering all engineering schools, and are valid for showing the trend. At first glance, these proportions of increase seem rather satisfactory except for the fact that the range between Professor and Instructor is being decreased, which has the disadvantage pointed out earlier. However, a closer scrutiny shows that the percentage increase in the cost of living from the academic year 1935–36 to the academic year 1946–47 as determined from the indices in the Survey of Current Business, Bureau of Labor Statistics, is about 55 per cent, which is much larger than the percentage average salary increase in any rank.

These cost of living indices are based upon the annual budget and cost of living of the better class skilled workmen, whose annual incomes, generally speaking, are commensurate with the lower academic salaries from Instructor through the average of Assistant Professors. It must be remembered that the outgo budget of a professional man,

TABLE 2

ANNUAL SALARIES OF FACULTY MEMBERS

Engineering Schools Arranged by Types of Institutions

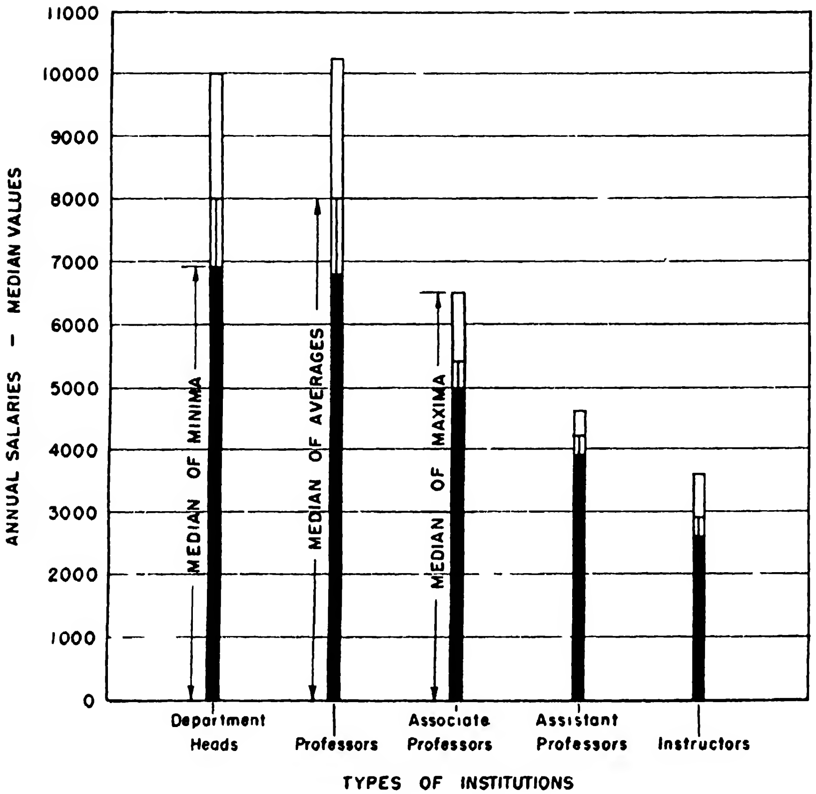
Median Values of Maximum, Average, and Minimum Salaries

Types of Institutions	No. of Institutions	Medians of Maxima					Medians of Averages					Medians of Minima				
		Dept. Head	Prof.	Assoc. Prof.	Assist. Prof.	Instr.	Dept. Head	Prof.	Assoc. Prof.	Assist. Prof.	Instr.	Dept. Head	Prof.	Assoc. Prof.	Assist. Prof.	Instr.
Endowed Universities	26	6000	6000 *	4500	4000	3000	5400	5000	4100	3400	2600	5000	4600	3800	3200	2600
State Universities	45	5700	5300	4100	3600	3000	5200	4800	3800	3300	2600	4800	4200	3500	3000	2300
Municipal Universities	6	6400	5600	4100	3600	3000	5600	4500	3900	3300	2700	5000	4000	3800	3100	2500
Endowed Polytechnic Institutes	16	7500	7000	5000	4200	3200	7400	6300	4500	3400	2600	5500	4500	4000	3000	2300
State Polytechnic Institutes	12	5100	4500	3900	3300	2600	4700	4300	3700	3200	2200	4400	4000	3400	2800	1800
State Colleges of Agri. and Eng'g.	19	5800	5200	4000	3800	3000	5200	4400	3800	3200	2600	4800	3900	3400	3000	2300
Endowed Colleges	15	5100	4900	4000	3500	2900	4800	4400	3800	3200	2500	4300	4000	3600	3000	2000
Military Colleges	4	4900	4500	3600	3300	2800	4900	4200	3500	3100	2500	4900	3600	3500	2800	2300

CHART II. ANNUAL SALARIES OF FACULTY MEMBERS

SALARIES IN TEN HIGHEST PAYING ENGINEERING SCHOOLS

Median Values of Maximum, Average, and Minimum 1946-47 Salaries



especially a teacher, should include expenses that a skilled workman has no reason to undertake (personal professional library, membership in professional societies and regular attendance at their meetings, etc.). These expenses cause the living cost increase to produce an additional impact on faculty members, especially Instructors and Assistant Professors with their smaller margins. Thus the indices provide a basis for determining the impact of the change in the cost of living on the two lower academic ranks, and a fairly reasonable basis for the two upper ranks as well.

Considering the medians of the minimum salaries paid, the percentage increases between 1935–36 and 1946–47 are approximately as follows: Professors 25 per cent, Associate Professors, 31 per cent, Assistant Professors, 36 per cent, and Instructors 52 per cent. The major portion of the salaries of the younger men on engineering faculties, especially Instructors, must be devoted to the necessities of life (shelter, food, clothing, medical and hospital expenses,

etc.) and these men have little leeway to meet increasing costs of living. Thus the engineering schools have done well to provide sizeable percentage increases, particularly for those receiving minimum salaries. However, a comparison with the percentage change in cost of living shows that the faculty salaries have lost ground in spite of the salary increases, and therefore faculty members are suffering financially, possibly even more greatly than prior to 1940 on the then lower salaries. This may be the cause of the difficulty in certain institutions that now are almost forced to appoint an untried man as an assistant professor, rather than as an instructor who normally is expected to receive more supervision than an assistant professor.

In any activity, whether education, industry, business, government, or sports, it is desirable to establish "par for the course." With this thought in mind, the ten institutions were selected which pay the highest average salaries of Professors. Chart 11 shows the medians of maximum, average, and minimum salaries for Department Heads and the four academic ranks at those institutions. It will be noticed that the median of the maximum salaries for the professorial group is greater than for the Department Heads. This is because three of the ten highest paying institutions do not have the permanent rank of Department Head; the members of the department staff rotate in the responsibilities of chairman of the department without increase in salary. From this chart the medians of average salaries of the ten highest paying engineering schools are as follows: Professors $8,000; Associate Professors $5,400, Assistant Professors $4,200, Instructors $2,900.

These values can be serviceable to the engineering schools when considered as "par." It appears desirable for an individual engineering school to compare the average and minimum salaries at its institution which are paid to each of the four academic ranks with the corresponding values shown on Chart 11—making the comparison both with weight given to the specific living conditions at the location of the institution and also without such consideration. This should produce salary figures which would be to the best interest of the particular engineering school to achieve. If the average salaries at every engineering school approached the values in Chart 11 of medians of average salaries, a much larger proportion of the young engineering graduates would be attracted by the possibilities of the teaching profession. Moreover, there are many men in business and industry with fine qualifications for faculty positions (but with obligations pressing them toward the higher paid industrial or business employment) who would be in teaching positions because of tastes leading them in that direction if the educational salaries were more generally desirable.

Comments

The loss in relative level with respect to industrial and business salaries is not limited to engineering school salaries. Professor Sumner H. Slichter of Harvard University found from a study of the returns from 88 colleges and universities that the academic salaries, including all departments and schools, are on the average lagging even more seriously than those of the engineering faculties. This information is incorporated in his article entitled "What Has Happened to Professors' Salaries Since 1940" in the

Winter 1946 issue of the *Bulletin of the American Association of University Professors,* page 718. Professor Slichter found that, "The sort of two-way communication and carefully organized consultation which one now expects in all progressive and well-administered organizations rarely exists in the administration of the budgets of colleges and universities." He recommended the establishment of a special faculty committee on the budget, which committee would *not* have final determination of faculty salaries but would review the budget and offer criticisms and suggestions, thereby bringing to bear upon the proposed budget the experience and judgment of the faculty in a purely advisory manner. He further recommended the adoption of definite program and time schedules for the restoration of salary scales of pre-war purchasing power.

Professor Slichter found that faculties now are called upon to participate more generally in the formation of educational policies than in budgetary matters. It should be borne in mind that the development of educational policies and a knowledge of financial policies are complementary because the latter supports the execution of the former.

It is evident that desirable increases in salary have been brought to pass since the middle 1930's. However, it is equally as evident that increases in salaries in general are entirely inadequate to compensate for the increase in cost of living that has occurred since 1940. Although a detailed study of industrial salaries has not been made, general information available of salaries paid to engineers by various industrial companies makes it apparent that engineering school salaries still fall too far below those of engineers in industry who have equivalent capacity and exercise responsibilities commensurate in importance.

We must remember that, for the best interest of engineering education and therefore for the best interest of the entire engineering profession and the nation, it is important that engineering school salaries and opportunities shall be such that they will attract the young men with the most creative minds in research and teaching—which minds are backed up with enthusiasm and industry. Therefore it becomes of the utmost importance that general advances of salary scales be made, especially in certain regions and certain types of institutions. In making such advances, except in those institutions which have maximum salaries for Professors of $10,000 or more per academic year, serious attention should be given to the wisdom of increasing the range between the median of average salaries of Instructors and of Professors.

On the Status of Engineering Research in Electronics*

By HARRY DIAMOND

Chief, Ordnance Development Division, National Bureau of Standards

I consider electronics as a science, an art, and an industry. The first phase, science, supplies the basic knowledge upon which electronics is founded. The second phase is the art of engineering research necessary to transform the fundamental knowledge of pure science into practical design factors and instrumentations useful to technology. The third phase is that of applied technology directed to satisfying the material needs of mankind. As of principal interest to this audience, I shall discuss primarily the present status of the second phase, engineering research, and shall attempt to illustrate fruitful directions for further work in this phase of electronics. However, it is not possible to present a clear picture of the state of affairs in electronic research without touching upon the other two phases. The intervention of the war has operated to throw out of balance the inter-relationship normally developed between pure science, research, and commercial application.

The problems currently facing electronics engineers may be stated as follows:

We of the electronics engineering art emerged from the war extreme optimists. Electronics had done such a marvelous job in the war that we felt it had reached a state of advanced perfection and saw unlimited opportunities for its application to peacetime uses. However, upon consideration of our peacetime problems, we began to note a variety of disturbing factors which previously had escaped our attention. Statements by eminent scientists began to appear deploring the lack of progress in pure science during the war and the dearth of trained scientific personnel. We noted further that the normal needs of our economy had been maintained in a state of suspended animation pending the successful conclusion of the war. Meanwhile, the attention of the end users of the products of scientific achievement had been focused on the great accomplishments of science. The nation now awaited the peacetime equivalents of the spectacular wartime scientific applications. The overwhelming scope for the application of new methods, new materials, new tools, and *above all* new ideas to the fulfillment of existing needs was admittedly inspiring; however, we knew that for a variety of reasons the public could not obtain at once, nor could be

* Presented at the Southeastern Section A.S.E.E., Louisville, Kentucky, April 17, 1947.

promised for the near future, the technological marvels it had come to expect. Finally, the unexpected need for perfecting our national defense at the same time that we drove toward our potential peacetime stride added still further immensity to the job expected of us. It was upon realization of the position into which the pressure of the times had forced us that we electronic engineers first had our rude awakening from the optimism into which we had drifted.

An accurate appraisal of our position requires examination, first, of the problems beyond the control of the research engineer. These are the oversold public, the lack of trained personnel, and the retarded rate of progress of pure science. Once we have considered these problems, it will be possible to proceed to a detailed analysis of the state of affairs in engineering research. This is the most optimistic phase of the picture in electronics, although even this phase is spotty in some branches. From the detailed analysis, I shall attempt to show that:

(1) The emphasis in engineering research during the war has in considerable measure advanced our knowledge of materials, design techniques, and instrumentation, required in applying scientific principles to practical end uses;

(2) For the immediate future at least, there appears to be no discernible dearth of fundamental principles on which to base engineering research;

(3) There is much need for accelerated research to assist in meeting the demands of society; however, by redoubling our efforts we are in position to meet most of the reasonable demands; and,

(4) For the long-pull, we must rely on the pure scientist to widen the gap between fundamental knowledge and engineering application and, perhaps, we must even find ways of helping him do so.

I. Consideration of Problems beyond the Control of the Engineer

Let us dispose briefly of the problem of dissolving, in some measure, the degree of public expectancy of miracle electronic products. A thrilling prospectus has been built up in the public mind, without differentiation between *currently feasible* and *coming* embodiments of useful devices. The exponents of the *electronic age,* no less than the exponents of the *push-button war,* have done considerable mortgaging of the future. The immediate danger is that there may arise an aftermath of disillusionment which will build up considerable sales resistance on the part of the ultimate user. Somehow, the public must be made aware of the actual state of affairs. It is exceedingly important that an exact picture of the true status of electronics, neither overly optimistic nor overly pessimistic, be presented to the public. An encouraging phase of this problem is that the public relations men in industry have become keenly aware of it. Prior to reconversion, it was deemed good advertising to focus the public's attention on promised products; it has now become advantageous to sell the items that are coming off the production line. The latter approach, coupled with the few really new products which are beginning to appear,

should provide an effective stop-gap during which the engineer may concentrate on the perfection of the promised new devices.

Next, let us consider the current lack of sufficient numbers of adequately trained personnel to handle the multitudinous research programs in hand. This is by far the most difficult problem. The principal single factor retarding many a program today is the inability to acquire high-caliber technical personnel. The training of such men is a matter of years of preparation and cannot be extemporized. The war was allowed to interfere seriously with advanced training in the basic sciences and, now, time alone can cure the situation. I am aware of the strenuous effort currently being exerted by the colleges and universities represented at this session towards meeting this problem.

Finally, let us consider the status of pure science upon which we must eventually stake our future. We must, albeit reluctantly, take the word of eminent scientists that the problem here is serious. Quoting from an article by I. I. Rabi [1] on A Physicist Returns from the War, we have the following excerpts:

"By the very success of his efforts in this war, the physicist has been placed in an embarrassing position.

"Industry, with considerable success, is trying to lure him from his academic hide-out with glittering pieces of silver and with the promise of unlimited scientific equipment.

"Our rejuvenated military forces are building giant laboratories (any one of which can use up all of our currently available and really trained physicists).

"The universities hope the physicist will return to satisfy the needs of students.

"The embarrassment of the physicists stems . . . from their realization . . . that in the past five years, apart from the development of certain techniques which may be useful in later research, the progress of the science of physics has been less than moderate.

"With atomic bombs and radar in mind, the skeptics may well ask what the physicist thinks he has been doing these past five years, if not physics.

"To answer them the physicist must attempt to explain the two aspects of his science. There is, first, the creative intellectual activity which constantly pushes back the boundaries of our understanding of natural phenomena; second, the industrial activity which applies the results of scientific knowledge and understanding to satisfy material human needs and whimsies. The first is the science of physics proper, and the second is the side of physics which has been called the inheritance of technology. If the science of physics lags, the inheritance of technology is soon spent. In the war years, the inheritance of technology has been exploited to the point where further substantial progress can come only from an advance in the science of physics"

A corroborative view is that of Raymond B. Fosdick, President of the Rockefeller Foundation, expressed in a newspaper editorial [2] digesting a portion of his Annual Review. Although the field of science discussed is Medicine, the remarks are clearly applicable to other branches of science. I quote:

"Nothing that war touches escapes blight. There is a popular belief that science made rapid progress between 1939 and 1945; but this belief has little basis for support. It is now generally recognized that the feverish activity of scientists in wartime is essentially not scientific. They are primarily engaged in the application of existing knowledge to certain specific and narrow problems.

[1] *The Atlantic Monthly*, October 1945.

[2] *The Washington Post*, March 22, 1947.

They have no time for pure research and their contributions to basic knowledge are infrequent and on the whole unimportant. They are drawing on the reserve of the past. They are using up the supply of basic discoveries which an earlier generation has given them. They are digging recklessly into the stockpile of existing knowledge. The gap between knowledge and use in science is always narrow; the effect of war is to close the gap almost to the vanishing point. . . ."

It is difficult to express correctly a man's philosophy by brief excerpts from a single statement. And yet Dr. Fosdick and Dr. Rabi, in two separate fields of science, say that technology, rather than basic knowledge, was advanced during the war. Both agree that engineering application has caught up with pure science. Both see the need for further advances in basic science for future needs of mankind. For myself, I am inclined to question somewhat timidly the scientist's pessimism on the state of his science. Perhaps I entertain the hope that the situation has improved in the eighteen months since Dr. Rabi's article appeared. Perhaps it is because I am so much impressed with the diversified instrumental tools which electronics is providing in aid to pure science. The emphasis has heretofore been, with complete justice, on how technology leans on scientific advances. The other side of the story, wherein technology contributes to the pure sciences, has in my estimation not been sufficiently pictured. Experimental technique would appear to me to comprise a major factor in modern fundamental research. Investigators in experimental physics, seeking to further the knowledge of the nucleus, the atom and the molecule, appear to me to spend much of their time in developing the instruments with which to carry on their investigations. I will show in my survey of electronics research and development that there was material advancement in basic instrumentation during the war, and even in methods of computation. I believe that these achievements will reflect as material gains to the advancement of pure science.

II. State of Affairs in Electronics Research

The remainder of my discussion will be directed to an examination of the principal branches of the electronics art, with a view: (1) of disclosing the current state of affairs in engineering research in each branch; and (2), of indicating areas in which intensified research appears to be needed.

I find that I must digress briefly, however, in order to define what I mean by engineering research and development and, in that process, to attempt to define science, also. Certainly, if science and engineering are to be mutually exclusive, we as engineers cannot accept Dr. Rabi's possessive reference to the second side of physics which you will recall he labelled the industrial side or the inheritance of technology. Such reference disinherits our profession of what to me represents its most alluring phase, namely, engineering research and development. I consulted the Merriam-Webster dictionary, frankly, with the view of refuting this coup d'état on the part of the physicist. The definitions I liked best follows:

Science—a branch of study which is concerned with observation and classification of facts, especially, with the establishment (and, strictly, the quantitative formula-

tion) of verifiable general laws, chiefly by induction and hypothesis.

Physics—the science which deals with those phenomena of inanimate matter involving no changes in chemical composition, or, more specifically, with the most general and fundamental of such phenomena, namely, motion; *i.e.*, the science of matter and motion. Physics is usually held to comprise the closely related sciences of mechanics, heat, electricity, light, and sound, and the branches of sciences devoted to the study of radiations, and of atomic structure.

Engineering—in its modern and extended sense, the art and science by which the properties of matter and the sources of power in nature are made useful to man in structures, machines and manufactured products.

Fortified by these definitions, I feel free to proceed to offer my views as those of an engineer practicing engineering research in electronics.

The truth of the matter is that it is well-nigh impossible to distinguish between *applied physics* and *engineering research*. Activities in electronics during the war present a striking example. As you know, developments in electronic ordnance proved quite spectacular. The proximity fuze and the guided missile are specific examples. The nature of the technical difficulties encountered and of the technical skills required of the workers in this field was not unlike that for radar. An analysis reveals that the structure of representative groups in these two fields was also not dissimilar. Of the 48 senior members of the Ordnance Development Division of the National Bureau of Standards, 29 are classified as physicists and 16 as engineers. As of August 1945, the Coordinating Committee of the M.I.T. Radiation Laboratory comprised 66 members, of whom 45 could be identified as physicists and 15 as engineers. We at N.B.S. are inclined to classify our work as primarily engineering research, whereas I am quite sure that the physicists in charge at M.I.T. considered that they were working in applied physics. Perhaps a compromise term, such as *engineering physics*, might be applicable.

A. A Survey of Electronics

It appears appropriate at this point, also, to introduce a definition of the term *electronics*. I shall quote briefly from a recent address of E. U. Condon, Director of the National Bureau of Standards.[3]

"Electronics has not been given, as far as I know, an officially agreed-upon definition. Generally speaking, . . . it is the science, art, and industry concerned with electrical phenomena involving electrically charged atomic particles, outside of solid and liquid bodies. With this understanding, we have a fairly clear separation of the field from the classical branches of electrical engineering and at the same time a definition that is broad enough not to restrict us to those particular phenomena in which only electrons are involved.

"Electronics is thus a very broad subject. It embraces all phenomena connected with the passage of electric currents through gases and high vacua. Such phenomena are utilized for a wide variety of purposes: the generation of high frequency electric power, its amplification, the control and rectification of electric power at all frequencies, production of electric current from light sources,

[3] *Electrical Engineering*, April, 1947.

and production of light from electric currents (including X-rays and gamma rays as special forms of light). Phenomena associated with the propagation of radio waves in the ionosphere are of course also included, as is the study of cosmic radiations from interstellar space, and special means for producing beams of atomic particles of high energy for the study of nuclear physics."

Based on Dr. Condon's summary definition and partly on the body of his address, I present herewith a partial list of branches of electronics of interest to the engineer:

(1) Radio communication and broadcasting, including television and facsimile.
(2) Electronic ordnance, including radar fire-control, electronic controls for guided missiles, proximity fuze, and electronic controls for underwater torpedoes.
(3) Radio navigational aids, including radar, loran, and other sea and air navigational aids.
(4) Electronic power conversion, including dielectric and inductive heating.
(5) Electronic instrumentation and controls, including special instruments for physical, chemical, medical and biological research and practice, and the general concept of the servo-mechanism
(6) Electronic devices for mathematical computation.

Basic to all of these branches are the electron tube and the electronic circuit. The diversification of form, function, and complexity of each is well-known. Each presents a fruitful field for research basic to the entire art. Knowledge of the properties and design of electron tubes and electronic circuits was materially increased as a result of the major application of electronics to war purposes. It is only necessary to mention the rugged subminiature proximity-fuze tube, the magnetron, the klystron, the traveling-wave amplifier tube, the image-orthicon, the "memory" selectron, and the hydrogen-thyratron, to call to mind the degree of recent effort in the electron tube art.

Similarly, the printed circuit, the microwave plumbing, the resonant cavity, the dielectric-heater electrode, new pulsing techniques, and various forms of new antenna, illustrate some of the activities in electronic circuits. Associated with tubes and circuits may be found practically every component and instrument familiar to physics, chemistry and engineering. Despite the wartime accomplishments, intensive research effort is now in progress, and will be required for many years to come, towards furthering the knowledge of fundamental phenomena in these fields.

For example, in electron tubes the oxide coated cathode is used extensively, yet very little is understood about the mechanism of electron emission from oxide-coated surfaces. Although increased understanding of the phenomena is of basic importance generally, it is particularly urgent in the case of pulsed, high power tubes. It is encouraging to report that research projects on thermionic emission from coated surfaces are under way in several institutions, but in this field there is little doubt that applied research is treading close on the heels of fundamental science.

Also, within the electron tube, it must be admitted that the nature of secondary emission, both from metallic and dielectric surfaces, and the nature of ion formation are subjects about

which we really know very little. Although much applied research, involving mainly circuitry, can be done with tubes we now have, further advances in the tube art are greatly dependent on continued discovery about emission and ion formation.

B. Radio Communication and Broadcasting

During the war, great advances were made in the knowledge of the factors affecting the propagation of radio waves throughout much of the radio-frequency spectrum. The influence of the ionosphere and of the troposphere under varying meteorological conditions is now much better understood. The importance of such increased knowledge in the physics of radio propagation can hardly be overestimated. It is now possible to prepare predictions of conditions affecting radio propagation sufficiently well in advance and of an order of accuracy such as to be extremely useful to the radio communication and long distance aerial and sea navigation services. There is ample room for more basic research, but certainly the war caused no halt in this field of study.

Radio communication and broadcasting cannot escape benefit from the increased knowledge of radio propagation and from the advances in tube, antenna, and circuit theory and technology resulting from the major application of electronics to war purposes. It might be said that the application of television, frequency-modulation and the like to the entertainment services was held up, but there appears to be no technical reason why these services should not attain major proportions very promptly. For example, now that the Federal Communications Commission has ruled that more research is needed on color television, the industry is turning to development of nation-wide black-and-white service. Concurrently, basic research on electronic methods of color television should proceed.

I shall not attempt to detail possible avenues for research in this oldest field of electronics.

C. Electronic Ordnance

The branch of electronics called electronic ordnance is primarily a product of World War II. It has a short but brilliant past and a great future, but presents many technical challenges. Naturally, I cannot discuss these in detail because of the necessary military security restrictions imposed. However, merely a list of some of the applications, such as radar fire-control, electronic controls for guided missiles and underwater torpedoes, the proximity fuze, and electronic bomb and rocket directors, provide an indication of the scope of activities in this field. A further indication is that officers of the Army and Navy ordnance development agencies now sit on technical committees discussing electronic tube and component developments. Research in this field cuts across the electronics art and, at the same time, is intimately associated with several other arts. In certain applications, such as the proximity fuze, the development of processes, instrumentation and techniques for furthering mass production is nearly as important as the development of the devices themselves, since during the latter months of the war some 25 per cent of the capacity of the electronic industry was devoted to the manufacture of this device.

The retreat of technical men from this branch of electronics, as from other military research activities, is a

source of much concern to those responsible for our national defense. The technical challenges are such as to require personnel of highest caliber and training. The results of research in this field will undoubtedly prove of value to other branches of electronics, such as radionavigational aids.

D. Radio Navigational Aids

The public could be entertained by wired programs if radio channels did not exist. But an airplane, particularly during adverse weather conditions, must rely very largely on radio aids. This then is a true example of the application of science to extend man's power to see, hear or do beyond his own unaided capabilities.

It is a curious paradox that many such applications are based on too literal an interpretation of this aim and thus require the use of man himself in their ultimate utilization. This element was a necessary characteristic of many of the wartime radio and radar developments and its effect must be carefully considered when evaluating them for use as peacetime air navigational aids. The human factor in radar search, in voice communication, in underwater detection and in loran navigation was an important one. Upon the power of the eyes or ears to make a fine discrimination often depended the outcome of a battle. Psycho-physicists were busily devising means for increasing the sensory margin of the operator in order to get the most out of the man-machine combination. This was highly commendable under the circumstances and may similarly be useful in application to industrial practices.

It should be clearly evident, however, that radio aids to air navigation must place as little reliance on sensory margin as is humanly possible to achieve. The conditions of safety and reliability are so stringent that an accident rate during 1946 of 1.2 passenger fatalities per 100-million passenger miles in domestic air operation could be sufficiently over-shadowed by a few foreign accidents as to cause a Senate investigation. Although the record cited for domestic operations for 1946 is impressive, the actual situation leaves much to be desired when one considers the air congestion at and around airline terminals under adverse weather conditions; and this with only 650 airplanes in scheduled operation. The future of air transportation calls for much better scheduling of a much greater air fleet with at least an equal record of safety. Viewed in this light, the requirements imposed on a basic system of radio aids are tremendous.

Ultimately, it appears necessary to bypass the human navigator altogether, and to apply the navigational intelligence directly to the controls of the aircraft. In considering the division of responsibility between ground controllers and crews of aircraft, it will be seen that the ground controllers should establish the flight plan which is to be followed, and that the air crew should be given sufficient information to carry out that plan with minimum reference to the ground controllers. In a completely automatic system, the air crew should have means for correcting the flight of the craft if it does not adhere to the desired plan, or for deviating from the plan in case of emergency. The ground controllers should have continuous automatic monitoring of the position of each craft in flight and of the degree of its adherence to the prescribed plan.

Automatic ground computers and associated automatic pictorial display of the monitored data will undoubtedly be required to provide for efficient traffic control. Rapid communication between the air crews and the ground controllers will obviously also be essential.

Today no basic system exists which can conceivably do a 100 per cent job of this sort. This is clearly recognized by the aviation industry and by the responsible governmental agencies of the world. It is to the credit of all these, however, that really constructive measures have already been taken, on an international basis, to assess the systems now available, to standardize those fitting into an ultimate plan, to promote the development of other systems applicable to this plan, and, finally, to define the functional requirements for the elements of such an overall plan. Nevertheless, we have a state of affairs where extraordinary needs exist for radio aids which are, however, not available in their preferred forms. An intense effort of research and development is accordingly indicated, if the important air transport industry it to attain its potential proportions.

In the few minutes that I can devote to this subject, I shall attempt to accomplish the following objectives:

(1) To review briefly the present state of development of radio aids to aviation;

(2) To assess the influence of wartime experience upon them; and

(3) To indicate the areas wherein research development work is vital. (I have already discussed the aims to which such work should be directed.)

A digest of the conclusions and recommendations of the international body (Provisional International Civil Aviation Organization) which met in Montreal in December 1946 to consider this problem will serve very closely for my presentation.[4]

The ultimate goal adopted was to provide a unified system of radio aids comprising *communication, navigation, traffic-control* and *collision-warning* services suitable for use under all flying conditions and in all parts of the world. Functional requirements were set up for the basic elements of this ultimate system but, recognizing the long range aspects of fulfilling such requirements, a set of immediate objectives was adopted for interim application.

The basic *functional requirements* were directed to the continuous safe and efficient movement of air traffic, founded on effective navigational aids along all portions of the route to be flown, including take-off and landing. Emphasis was placed on an integrated system with automatic features wherever possible, but with considerable freedom for deviation from the prescribed plan, when essential, on the part both of the air crew and of the ground controllers. Visual display of information to the air crew was also emphasized. Even in communication, it was recommended that long instructions be recorded either by facsimile, by teletype, or by indicator signalling. Radar was found to have its principal

[4] Final Report from the Chairman, C. O. T. Division (Radio Technical Division) to the Chairman, Air Navigation Committee, Provisional International Civil Aviation Organization Doc. 2553 C. O. T./28, dated Nov. 29, 1946, presented to the Council of P. I. C. A. O., for consideration at the Dec. 1946 Meeting in Montreal, Canada.

field of application in traffic control and collision prevention aids, although having auxiliary functions in short distance radio aids and in landing aids. Because of the increasing range of operation and speed of aircraft, short-range aids as well as landing aids were conceived to be increasingly associated with the traffic control system. Accordingly, automatic features were particularly stressed for these aids. Major facts to be highlighted are:

(1) that the systems found most applicable for the short-distance and landing aids were developed well before the war;
(2) that, in the primary fields of application of radar, considerable development will be required before the inherent functional requirements can be met practicably; and
(3) that for long-distance navigational aids, LF loran, developed during the war, is undoubtedly the best available although not readily adaptable to automatic navigation.

For interim application it was found possible to define certain *immediate objectives* which may be fulfilled by currently available systems. The more important definitive recommendations were:

(1) The ILS system of landing aids was standardized and recommended for installation at all airports used by international airlines at the earliest possible date and in any event not later than January 1, 1951. Such installations were defined to include a VHF runway localizer, a VHF guide path transmitter and three VHF markers. Provisions were made for substitution of a phase comparison localizer for the equisignal type any time after January 1, 1951, and for the use of medium frequency D. F. beacons at the approach and middle marker beacons, if desired. Further provisions were made for the additional use of Ground Control Approach radar as an aid supplementary to the standard system where local conditions warranted. (In the interim report of the U. S. Senate Committee on Interstate and Foreign Commerce, ILS and GCA are recommended for joint installation at the principal U. S. airports).[5]

(2) The VHF omnirange, in combination with distance measuring equipment (DME), was recommended (but not standardized) for use on all international trunk routes where short distance navigational aids are required. The omnirange is to be of the CW phase comparison type, so that where the runway localizer of ILS is of that type, the same aircraft receiving set may be used. DME is the usual radar transponder beacon type. Considerable leeway was left to individual countries, for use on a regional basis only, of such aids as are now available or under development; for example, the Australian multitrack pulse range together with DME, the American low-frequency omnirange, etc.

[5] Interim Report of the Committee on Interstate and Foreign Commerce, U. S. Senate, titled "Investigation of Air Safety," Feb. 22, 1947. (Senate Report No. 36, 1st Session, 80th Congress.)

(3) LF loran was recommended for installation to investigate coverage of critical areas within regions indicated on priority lists, such installations to be limited to those necessary to meet the operating requirements on international air routes in those areas. Standard loran and other existing long-range navigational aids, such as Consol, were recommended for retention or extension to meet traffic requirements.

The P. I. C. A. O. plan of ultimate functional requirements and immediate objectives for interim application points up an immense field for engineering research and development. The central problem for future development is that of short-distance and terminal handling of traffic. To this problem must be drawn much of the advancing art of guided missile controls, radar, and automatic computing methods. Here, the results of military research may be applied to current civilian needs.

E. Electronic Power Conversion

This represents the volume-sales branch of industrial electronics. Applications of electronic power conversion are extremely diversified, including rectification, electroplating and electrolytic processing, and frequency conversion. A very substantial fraction of the electric power generated during the latter years of the war was converted to direct-current by mercury-arc rectifiers for the electrolytic refinement of light metals. Many other industrial processes utilize power converted from the 60-cycle supply by means of electron tubes and other electronic devices. *Frequency conversion* is a particularly important form of power conversion; for example, the 60-cycle power is converted to power at frequencies up to hundreds of kilocycles for *induction-heating* and up to hundreds of megacycles for *dielectric heating.*

In this country, existing installations of induction and dielectric heating equipment alone employ more large electron tubes than are used in radio broadcasting, communication, television, etc., throughout the world. Potential requirements for electronic heating are expected to increase this margin by a large factor. Indeed, major competition is now in progress between the electrical utilities and manufacturers and users of electronic heating equipment on the one hand and radio communication and broadcasting interests on the other hand for the assignment of radio frequencies. The problem lies in the fact that very important new industrial processing methods may be endangered and corresponding valuable electrical loads may be lost to the electric power companies if too stringent regulations are imposed on the frequency stability and/or electrical shielding of such industrial electronic equipment in order to minimize interference with the communication services.

For maximum exploitation of new applications, more information is required on optimum and usable frequencies for the diversified products or materials which may be processed by electronic heating. The Federal Communications Commission has recently assigned a wide range of spot frequencies for this type of equipment. Instrumentation and data to allow the user to determine the optimum frequency for his product are vitally needed.

In this field of power conversion,

manufacture of the product as well as use of the process is highly decentralized. The capital required in manufacture is relatively small because the components (exclusive of tubes and power transformers) are inexpensive and no heavy machinery is required. There is considerable room for the exercise of individual ingenuity and inventiveness to find the solution to specific application problems. Because of this situation, the industry has great need for authoritative information on pertinent design factors. For example, one manufacturer considers his outstanding problem to be the design of a 1,000-KW unit which will operate efficiently with loads varying rapidly from 5 to 150 per cent of full-load rating.

It will be evident to this audience that the college engineering research laboratories can make vital contributions to this field. On its part, the National Bureau of Standards is investigating wherein it may be of service, within its prescribed sphere of activities. The work involved is straightforward engineering development and can in no sense be considered to be awaiting new basic scientific discoveries.

F. *Electronic Instrumentation and Controls*

This is a field of application of electronics which has virtually no limits. It advanced very materially during the intensive wartime exploitation of electronics. As might be expected, *electronic instrumentation* serves much the same purpose in industry as in science. The essential difference is that, in manufacturing, the measurement or analysis is made in connection with controlling the quality of a process or of a product; whereas, in scientific investigations, greater accuracy and rather more basic information are often sought. Electronic instrumentation provides a whole series of new approaches without which recent advances in science and engineering would have been well-nigh impossible.

In simpler applications of electronics to measurement and analysis, the basic elements of the instrument comprise a transducer for changing the function measured into an electrical impulse, an amplifier, and an indicator. For instrumentation of the type indicated, there is need for the development of standard basic elements which may be combined to perform a wide variety of functions.

In many instances, telemetering is required for transferring the indication to a point remote from where the actual measurement is made. An example of this is the analysis of stresses in airplane structures by instrumental, transducing and amplifying means on the airplane with the recording means on the ground. Telemetering is then accomplished by a radio link. Until recently, the radio sonde was perhaps the best known example of the use of electronic telemetering in instrumentation. Currently, our knowledge of the physics of the air is being expanded by instrumentation, including telemetering, carried into the upper atmosphere by the German V–2 rocket. In its tests of the missile in New Mexico, the Army Ordnance Department has afforded participation by a group of scientific organizations to conduct parallel investigations on the physics of the upper air.

The tremendous scope for electronic instrumentation can hardly be overemphasized. Precise measurement is the essence of science and of industrial processing. Electronic instrumentation affords a flexibility virtually be-

yond that of previously known means. There is ample room for research work in basic electronic instrumentation to exploit fully its potentialities.

There is a special class of large electronic instruments, developed primarily by the scientist and of particular value to the experimental progress of basic science. This class of tools includes mass spectrometers for chemical analysis and process control, devices for accelerating electrons and ions, and devices useful in the application of radioactive elements to industrial purposes and to medical research and practice. One needs only to mention the electron microscope, the cyclotron, the betatron, the synchrotron and the linear accelerator to indicate the scope of this type of application. I saw recently a list of such instruments being installed, or planned for installation, in scientific institutions of the United States; the numbers and the ratings in hundreds of megavolts were impressive. I would judge that the costs in megabucks were equally so. The outlook is for great scientific advances from the use of these installations. The scope for research on improving instruments of this type, or devising new ones, would appear to be large.

Electronics control to quote a recent article in *Fortune* [6] "increases the efficiency, safety, and control of power, flight, machines, and automatic processes, and is in wide expansion." The same article states:

"Probably less than 5 per cent of industry is equipped with electronic devices that it could profitably use. If it were fully equipped, the effect might be like that of transforming the average workman so that the power of his senses, and his mental and physical endurance, were multiplied a thousand times."

[6] *Fortune,* Vol. 33, Nos. 1 and 2, Jan. and Feb., 1946. American Productivity, I and II, by Charles B. Walker.

As in the case of electronic instrumentation, the diversification of potential applications of electronic control devices is awesome. The relative importance of specific types of application is necessarily based on the extent of their utilization. For example, a large majority of the automobiles produced in Michigan have their frames welded by machines using a special type of electron tube, the ignitron, which controls the welding process.

A typical use of electronic controls is for maintaining constant temperatures in the furnaces of the metallurgical industry. The critical factor in this application is the degree of accuracy attainable. This involves devices for the measurement of temperature, electronic devices for translating the measurements into control forces and means for adjusting the furnace temperature in response to the control. This type of "closed circuit" control is typical of a new and large class of devices known as *servo-mechanisms.* The advent of electronic sensory elements and amplifier equipment has been a tremendous step forward in the development of the servo-mechanism. The use of servo-mechanisms is as widespread as the need of industry for accomplishing correction of changes in some condition in response to detection of such changes. In this sense, the servo-mechanism has come to be defined and analyzed as a type of feed-back amplifier. In certain applications, it is evident that the amplification, conversion, and transmission of forces involved may be accomplished mechanically. However, the flexibility afforded by electronic controls, including the readier means avail-

able for correcting time lags, hunting, etc., accounts for the invasion of electronics into this field.

A fertile sphere of application of electronic controls lies in industrial processes which require close control of several conditions and of the constituent ingredients to secure a satisfactory product. Often the end product is analyzed at frequent intervals and, if not of desired quality, rather involved computations are made to determine the requisite adjustment of conditions or ingredients. It is within the possibilities of the present state of electronics to accomplish the analysis, the computations and the adjustments automatically so that the quality of the product may be kept continuously at the highest possible level. The overall electronic system may be considered a super servo-mechanism since, in the sense of the feed-back loop definition, departure from desired quality of the product is detected and automatically minimized.

It will be evident that there is great need for vigorous exploitation of this field in cooperation with industry. Such work will necessarily involve the development of new methods and the systematization of fundamental data and pertinent design factors.

A factor which is believed to be operating against more widespread application of electronic controls in industry is the relatively short life and non-ruggedness of electron tubes and circuitry. In the application of electronic devices to the control of machinery or processes, it is important that maintenance requirements be minimized, particularly since many industrial plants do not have electronic engineers available.

Miniaturization of electronic circuits and components is also highly necessary in certain industrial applications. An electronic control device should form an integral portion of the unit it controls. It should, furthermore, constitute a readily replaceable unit. Only then will it be completely accepted by industry. Fortunately, the technology of the proximity fuze has gone a long way toward the ruggedization and miniaturization of electron tubes, circuits, and components; these techniques are now being adopted rather widely in the industry.

G. *Electronic Computing Aids*

The electronic digital computing machine is the latest example of the speed and flexibility afforded by electronic methods. I consider that the advance made in this field during the war represents one of the most important scientific achievements of the past decade. To introduce this subject, I quote from Dr. Condon's address:[7]

"Only those who are skilled in mathematical physics realize how very limited is man's ability to obtain analytical solutions to important problems in applied mathematics. Great as has been the progress of the past century, the time has come when many problems of great importance, especially in hydrodynamics, aero-dynamics and meteorology, can only be handled by methods based on elaborate arithmetical computation. For a good many years now it has been the practice to introduce artificial and unjustified approximations into the setting up of many such problems in order to reduce them to a form tractable by our limited analytical attainments. As a result one is often confronted with this unsatisfactory situation: A theoretical calculation is made and the results are compared with experimental data and discrepancies are found. The question now is, are these discrepancies

[7] Electronics and the Future, Oct. 3, 1946.

due to an improper physical formulation of the problem, or due to the inadequacy of the mathematical methods used in making specific calculations from a correct physical formulation? Such a situation is clearly intolerable.

"On the other hand, calculations required for problems of current interest are so elaborate as to require many man-years of work by skilled computers. Aside from the cost involved, such a situation slows down progress because one has to wait too long to get an answer by old-fashioned hand-operated computing machines.

"A good deal of progress was made during the war in opening up the field of application of electronic methods to rapid calculations. . . ."

Federal activity in the computing field stemmed principally from the efforts of the War and Navy Departments to acquire computing machinery constructed specifically for critical wartime computation needs. There were three significant developments in this period: (1) an electromechanical computing device (the IBM sequence controlled calculator) of the Harvard Computation Laboratory, (2) relay type computing machines of the Bell Telephone Laboratories, and (3) an electronic computing machine (ENIAC) of the Moore School of Engineering of the University of Pennsylvania.

The application of such machinery ranged from numerical solutions of problems involving nuclear physics, hydrodynamics, electromagnetic wave propagation, the computation of firing tables, the application of statistical sampling theory and the like, to inclusion as components in missile flight simulators and fire control apparatus. The need for high computation speeds was extremely urgent, and the digital machines developed to meet it played a significant role in shortening the conflict.

A significant result of the intensive development and use of the high-speed computing machines during the war is that designers have been provided with operating data that would normally have required many years for accumulation. Experience now indicates rather clearly both the merits and the deficiencies of existing machines. The consensus of expert opinion is that the potentialities of electronic machines surpass those of the electromechanical and relay types and that further development should probably be limited to the electronic field. It is also agreed that an unparalleled opportunity for design improvements is at hand and that electronic digital computing machines can be constructed that will far exceed the ENIAC in speed and flexibility.

Electronic digital computing machine development requires the cooperation of two groups: mathematicians, responsible for the mathematical performance requirements and for organizing the mathematical logic; and physicists and engineers, responsible for developing the basic functional organs and for the engineering design integrating these organs into a unit capable of performing the prescribed tasks. In the complexity of circuitry, this field probably exceeds radar. There is ample room for new ideas and techniques. The demands for such equipment promises to become of significant commercial volume.

Great need for electronic computing aids exists in industry, in the universities, and in the Government. In industry, for example, the super-servo system cited in connection with electronic controls will require automatic computing elements of varying complexity.

The need in civilian agencies of the Government arises largely from the new complexity of problems in the social and physical sciences. For example, the Census Bureau needs to speed up the processes of sorting and analyzing field data involved in the preparation of monthly reports on labor force and of import and export statistical reports. In typical instances, the number of records studied may run to several million. Speed of report is, therefore, essential. The Census Bureau has other computational problems which may be carried out practically only through the aid of electronic computing machines.

The Weather Bureau probably represents the outstanding example of need by a civilian agency for electronic computational aids. Here, the mass of three-dimensional weather data collected daily over extensive geographical areas must be interpreted to provide reliable weather forecasts. The dynamic theories of weather forecasting have apparently outstripped the capacity for computations required to apply these theories. The Weather Bureau is actively engaged in the study of problems the solution of which might be facilitated through the use of electronic computing machines. There is need for parallel study of basic computing systems and equipment designed to carry out the required computation.

Other civilian agencies having possible present or future needs for electronic computing machine facilities include the National Bureau of Standards, National Advisory Committee for Aeronautics, Civil Aeronautics Administration, and Social Security Board. For example, the Bureau of Standards requires the use of the most advanced types of computational aids in connection with a number of its scientific investigations as well as in its work on mathematical tables. Moreover, a proposed computation center to be operated by the Bureau will increase its requirements for such computational aids.

I shall not attempt to outline the present activity on electronic digital computing machines except for the mention of a partial list of developmental agencies which includes the Institute of Advanced Studies at Princeton, the Moore School of Electrical Engineering, the National Bureau of Standards, Harvard University, and the Massachusetts Institute of Technology.

III. Conclusion

In conclusion, I trust that you will agree with me that an examination of the actual state of affairs points to a great future for electronics and to a very fruitful field for engineering and physical research. Anyone who was present at the recent great convention of the Institute of Radio Engineers, where more than 11,000 engineers and physicists attended the technical paper sessions and some 14,000 the exhibit-packed Grand Central Palace, cannot have avoided catching some of the enthusiasm with which many of us are imbued. The emphasis of other scientific and technical societies on electronic matters emphasizes the importance of this branch of science. The history of the development of atomic energy teaches us that any great development will carry along with it important tasks for electronics. If we get an atomic power industry in the near future, it will be largely electronic in character because of the obvious necessity for equipping these plants with completely automatic control devices.

The Engineer Hates Grandfather's Horse

By W GEORGE CROUCH
Associate Professor of English, University of Pittsburgh

and ROBERT L. ZETLER
Associate Professor of English, Pennsylvania College for Women, and Lecturer in English, University of Pittsburgh

Dean E. K. Hobhouse, of Upsilon University, strode into the Chancellor's office. "Mr. Chancellor," he sputtered after the initial handshake, "Look at these statistics! Out of 200 freshmen enrolled in the School of Engineering who are taking English I, there are 18 per cent F's and 43 per cent D's. Now what the hell's the matter? Are our students, who get average or above average grades in their mathematics, chemistry, and physics so dumb that they can't master their own language, or are the standards of the English Department too high? Or maybe we have too many damned aesthetes teaching our boys!"

The complaint of Upsilon's Dean is a standard one in almost every university in the United States. The engineering teacher—and at times, even many English teachers of engineering students—realize that our present teaching of English to the embryonic engineer is sadly deficient. In the typical American university, the English Department has a polite condescension towards the School of Engineering. The English teacher himself, trained by a graduate school as a specialist in literature or in composition of the aesthetic type, often finds himself in opposition to the material to be taught the engineer and to the engineer's viewpoint. Having interests which are primarily artistic, he looks upon the aims of the potential engineer as too practical.

If he is assigned to teach a course in freshman English for engineers, he may give the students subjects for compositions which are divorced from their interests. Such subjects might range from a description of grandfather's old bay horse to the taste of celery, but he will never suggest that his students explain the operation of a governor or the use of an industrial incentive system. He fails to motivate his students through their existing interests.

The best composition is done when the writer has enthusiam for his subject, but the topics most often assigned by English teachers to technical students do not stir this enthusiasm. Is the average English teacher, then, fulfilling his obligation to the engineering student?

Unfortunately members of English departments look upon their schedules in schools of engineering as "necessary busy work." Heads of departments are only too pleased to farm out this work to any luckless graduate assistants who may be cajoled into taking

the job. The best men are occupied with teaching their favorite courses in the College to students who may some day become English teachers or who may develop an abiding enthusiasm for literature. The tyros who take the engineering student in hand often regard their job as distasteful, to be endured until they can get a teaching schedule related to their special interests.

What can be done to improve the teaching of English to engineers?

There are at least two possibilities. The first is the creation in the School of Engineering of a separate Department of English. Such a department should have its own head; it should be under the jurisdiction of the dean of the School of Engineering. Its faculty should be recruited from men who have been trained in engineering as well as in English The courses should be planned to appeal to the primary interests of the engineering student.

Both the faculty and the students should benefit by this plan.

First of all, it would effect a closer cooperation between the English faculty and the engineering faculty. English would become as much a part of the School of Engineering as the Department of Mines and Mineralogy is And the engineering teacher, knowing the sort of writing his students will need when they become professional engineers, will be able to give valuable advice to his colleagues in English in the planning of courses in composition. He will, moreover, frequently be in consultation with the English teacher concerning the type of literature which the engineering graduate ought to be familiar with.

Separation of the Department of English in the School of Engineering from the Department of English in the College will make it possible for the instructor to become a specialist in the teaching of engineering students. In place of the slipshod work of graduate assistants newly recruited each year for a distasteful task, there will be substituted efficient teaching by men specially trained to meet the problems of the engineer. Too many young men teaching technical students know little about the course material; too few are willing to learn. In senior courses centered on the writing of engineering reports and articles, the average member of an English department usually fails to understand the technical problems involved. An English faculty permanently attached to the School of Engineering would go beyond a superficial acquaintance with the subject matter.

Another advantage of the proposed type of organization is that it will result in more practical work for the student. The aesthete will be relieved from teaching in the Engineering School, and the relief will be mutual for student and teacher. Subjects for writing will grow out of the engineering work itself, with a consequent sharpening of student interest; the engineer's need for English will be apparent to him.

Because this plan will require special training for the English faculty—training as specialized as that of engineering instructors—salaries should be on the same level as those of their engineering colleagues. These salaries, in fact, should be part of the budget for the School of Engineering and should not come from funds allocated to the College of Liberal Arts. Only a well-paid English staff will produce the expected results.

If the School of Engineering is willing to provide the funds for this plan, it will be able to attract men with the

training and ability requisite for the teaching of English to engineers. Few graduate assistants will need to be used, and those few will have served an apprenticeship under competent English professors in the Engineering School. The professors themselves will be chosen because of their knowledge of technical as well as of liberal arts subjects. Training by this sort of teacher should generate enthusiasm for self-expression in engineering graduates.

For the first time the majority of students will probably look upon English as an essential part of their technical training. Taught by men sympathetic to the ideals of engineering writing, they will be stimulated to do work of high quality.

As in every change of organization, some disadvantages will naturally be apparent. An English staff chosen to serve the engineering students and giving courses aimed to satisfy practical ends might meet opposition from the students themselves, who already think that their curriculum is too full of technical courses. The right sort of teachers, however, will offer the broad training which the student needs. Such a plan as the one advocated here should turn out more literate engineers than the present system does.

There is also the possibility that this plan might emphasize the tendency to set apart the engineering student as a peculiar species, one removed from his fellows. But with the use of block sections in English, the engineer now has little contact with students specializing in other subjects. The objection, then, is hardly valid.

From the standpoint of the English faculty, there is the possibility that the School of Engineering may dominate its work. The system outlined above, however, should produce cooperation. The English staff, being part of the School of Engineering, will share its aims. There should be no basic conflict.

The question may be asked, "How will a faculty, properly sympathetic to the engineering program and its purposes, be recruited? Where are we to find men who have both an engineering and a liberal arts background?" Two answers suggest themselves. The professorial life and a good salary may attract the articulate engineer from industry, or these same rewards may influence the man trained in English to do collegiate work in basic engineering subjects before he begins his teaching career.

If the plan as outlined should make too sharp a division between the work in English in the Engineering School and that in the College of Liberal Arts, an alternate plan is suggested which should bring most of the benefits of the first plan to students and faculty. A subdivision within the Department of English could be established to serve the interests of the engineering student. A member of the English Department should be designated as the head of this subdivision, with authority to speak concerning English for engineers at meetings of department heads or conferences on engineering training.

Like the preceding plan, this form of organization would force recognition of the fact that the engineering student needs training in English different from that given to candidates for an arts degree. At the same time, the head of the subdivision, acting with the advice of his colleagues in Liberal Arts, could insure that the engineer's training would not be too narrowly practical.

One weakness might develop. Just as in the previous plan, in which there

was a danger that the Engineering School would exert too much influence over the content of English courses, so in this case the English Department of the College might force unacceptable subject matter on the faculty of the subdivision. A head who had a realistic approach to the problems of the engineering student might well overcome this disadvantage. Emphasis again should be given to the special training of the faculty constituting this subdivision. This entire plan would be unworkable, of course, if the head of the Department of English in the College were unsympathetic to the special needs of engineering students.

When these two plans are considered, it appears that the first has several advantages over the second. A separate Department of English for the School of Engineering would give its members freedom of action to work out plans in cooperation with the School of Engineering. In addition, the members would be able to confer when necessary with their colleagues attached to the English faculty of the College. The difficulties of setting up a department within a department would be avoided. The student would have the advantage of being taught by men who have specialized in engineering communications; he would be assigned more practical and interesting work. Either plan, however, would be more effective than our present inchoate system.

Modifications and Trends in Engineering Curricula*

By W. G. VAN NOTE
Director and Head; Department of Engineering Research, North Carolina State College

A little over a year ago Dr. Benjamin Fine, educational editor of the New York "Times," stated that "Nearly every institution of higher learning has one or more curriculum committees working on the problem of preparing plans to meet changing conditions of a world at peace." The accuracy of this statement has been amply substantiated by the frequency with which announcements have been released by colleges concerning their adoption of new curricula following committee reports.

Like so many other faculties during the past several years, those of the North Carolina State College have been engaged in extensive studies to formulate post-war plans. It was my interesting fortune to be active in the Planning Committee of our School of Engineering, which after more than a year and a half of study and deliberation made recommendations concerning post-war engineering curricula. During our work an appreciation was gained of the history of the development of engineering education to its present state of youthful maturity. My remarks here are a result of the impressions gained during the life of our committee.

* Presented at the Southeastern Section Meeting of the A.S.E.E., Louisville, Kentucky, April 18, 1947.

It seems proper that engineering curricula be continuously under scrutiny and subject to periodic re-evaluation. This is essential, first in the effort to assure that adopted curricula are adequate for current times, and second that curricula revisions be made in keeping with the changes in our society and technology that inevitably occur with the passage of time.

To say that times change is admittedly trite, but a striking, as well as an amusing, example of this truism was noted when we ran across the following rules from an American school as published in 1784.

> "We prohibit play in the strongest terms . . . the student shall rise at five o'clock in the morning, summer and winter, . . . the student shall be indulged in nothing that the world calls play. Let this rule be observed with strictest nicety; for those who play when they are young will play when they are old."

I wonder how many of you were on the golf course at some time during the past week or anticipate a foursome in the days directly ahead. It is doubtful if a sharper contrast can be found between former and current educational philosophies than this one just quoted.

The many institutions that have had committees busy with curricular studies these last few years include

both general and specialized colleges and schools. Among the general colleges, the Harvard Report, "General Education in a Free Society," has probably received the most widespread publicity. Shortly after this was made public, similar committee activity was reported from Princeton and Yale. In each recommendation, a common trend is noted. This is in the turning away from the free elective system which was introduced by President Elliott of Harvard more than sixty years ago and was accepted generally by most liberal arts colleges in succeeding years. While in the present recommendations elective privileges will be curtailed to prevent random choice, students will not be held rigidly to a fully prescribed program but will have limited electives from a group of integrated studies. Reports from many other schools indicate trends generally similar to those reported by Harvard, Yale, and Princeton.

Turning to a review of the picture in engineering education, it is profitable first to trace briefly its development.

Until about a century and a quarter ago, engineers prepared for their work quite as they had done through the fifty preceding centuries. It appears that there was much in common between the engineering training of those who built the pyramids and the ancient roads and aqueducts of Rome and those who built the Erie Canal. Both were taught by observation, practice, and apprenticeship.

However, in the middle of the 18th Century, schools for engineers were begun in Europe. The first of these were primarily for the training of military engineers, and it was only a short step from military to civil engineering. It appears that the first of these European schools arose in France, though one authority gives convincing proof that engineering education began in Germany, and further that these schools were initially inaugurated for instruction in the field of the mineral industries.

The development of engineering education in France influenced markedly the initial tendencies of similar instruction in this country. Rensselaer Polytechnic Institute began in 1824 as the first collegiate school of engineering in any English-speaking country. Its leadership had important influence on subsequent engineering education here, and since it had in turn been influenced markedly by France's Ecole Polytechnique, this French influence was transmitted to the United States. Simultaneously with this European influence on the initial development of our engineering schools, there was the influence of our own general college. This resulted from the introduction of engineering curricula into the general colleges between 1840 and 1860. In many instances, the engineering unit was dependent upon the support of the arts college and the philosophy of the latter was impressed upon the engineering educator. There was, indeed, at that time, engineering material sufficient only for about one year's instruction. The following is from an announcement from Rensselaer early after its inception.

"Students of the engineer corps are instructed as follows: Eight weeks in learning the use of instruments (as compass, chain, scale, protractor, level, etc.) with their applications to surveying, leveling, calculating excavations; eight weeks on mechanical powers, circles, conic sections, construction of bridges,

arches, railroads, canals, running circles for railways; four weeks in calculating the quantity of water per second supplied by streams as feeders for canals or turning machinery; four weeks to study the effect of steam and wind as applied to machinery."

There was also a strong influence of military educational philosophy on early engineering education. This resulted from a goodly number of West Point graduates resigning their commissions and accepting positions in the various newly assembled engineering faculties.

As the engineering curricula and faculties grew within the general colleges, there was inevitable conflict between the two groups, in method and viewpoint. It was not an easy time in the growth and development of engineering curricula.

A great stimulus to engineering education development occurred in 1862 in the passage of the Morrill Act, which created the great system of land-grant colleges and universities throughout the country. This Act gave general recognition to education in agriculture and the mechanical arts and insured the establishment of at least one institution directed to this aim in every state and territory. This led to a rapid expansion in the field of engineering education.

Another growth factor in the development and general public acceptance of engineering education was reached at the Centennial Exposition of 1876. There for the first time the public saw exhibits which included the Corliss engine, gas lights, and the electric generator and motor.

This public interest resulted in rapid technological strides, and by the time of the Columbian Exposition in 1893, engineering education and educators had attained a stature and a professional consciousness of such proportions that engineering education seemed now well able to stand without assistance from the general college. As a result of this, separate curricula, now quite divorced from the general college, were developed. As science and invention marched on, new machines and technologies were introduced, and there was great pressure to include instruction in these new fields in the engineering curricula. This was done at the expense of the social and humanistic courses, which earlier were there through the influence of the general college. It is also quite probable that this exclusion of these courses was furthered because of the lack of sympathy for them on the part of the engineering faculty, which had resulted from earlier clashes with the arts faculty and administration.

Feeling their professional consciousness and sensing their contribution to industrial progress, the engineering educators formed in 1893 the Society for Promotion of Engineering Education, now The American Society for Engineering Education. As you so well know, this Society continuously grew and has made itself felt tremendously in the general development of engineering education. From the turn of the century up to the time of the first World War, those responsible for engineering curricula probably felt their maximum freedom from the necessity of association with the social and humanistic influence. However, World War I began to awaken within the engineer a realization of the part he plays in the development of the culture as well as the civilization in which he lives. There were distressing results of embarrassment and humiliation from this appreciation.

The engineer began to realize that while he contributed markedly to the industrial development of his time, he had little understanding and less control over the social problems posed by the very industrial development he sponsored. References in our journals are legion concerning this gradual awakening among engineers to the fact that all was not ideal within the engineering curricula of the 20th Century. Repeatedly, engineers were referred to as the servants, not masters, of industry, the contributors to a technology, but seldom the leaders of a society.

There were those who felt that an engineering training was adequate to qualify one for successful participation in social and economic affairs without benefit of courses in the so-called "humanities." Yet by and large, this conclusion seems false. Professor Straub of the University of Minnesota spoke at a civil engineering educational symposium in 1941 on this question, and I quote him:

"I cannot agree that our much glorified 'engineering approach to a problem' is the panacea which the world has been awaiting. In fact, the technical procedures of the engineer, where not tempered by the perspective gained in studies in the humanities, definitely handicap him in his efforts to unravel social problems. He fails to recognize that the structure of social-economic order is dynamic and constantly changing—fundamentally different from technology. The ever-changing problems of human affairs do not lend themselves to fixed formulas as technology does, encompassed as it is by the rigid laws of the physical sciences."

There was also an increasing awareness of the change in our country, in the limits to further geographic expansion and a consequent re-definition of areas of possible service.

Dean Hudelson of the University of Illinois has pointed out that in that State whereas in 1870 there was an agrarian isolation with only 17 per cent of the population living in towns of 8,000 or more, there is now the industrial congestion resulting in 74 per cent of the people living in towns of more than 10,000.

Another trend of tremendous influence has developed since the formation of the A.S.E.E. This is the growth and popularization of higher education in general. It was more of a distinction to graduate from high school in the year of the founding of our Society than it is to graduate from a college today. Since 1893, there has also been a moderate expansion in a number and variety of engineering curricula.

It was inevitable that many pressing problems develop from the tremendous expansion of engineering education within the last fifty years. One of the most prominent and perplexing has been the inevitable crowding of a curricula limited to four years, and many have been the attempts to solve the problem this poses. Recognizing that no true solution was evolving, this problem led in 1939 to the formation within the S.P.E.E. of a committee on the Aims and Scope of Engineering Curricula under the chairmanship of H. P. Hammond of the Pennsylvania State College. The report of that committee has been widely studied and has had great influence on the trend of engineering education up to today.

Early in its deliberation, this committee noted that engineering is a functional branch of our national system of higher education, being the

technology branch in contrast to that of agriculture, economics, etc. Thus, it is not comparable to the professional schools such as Law, Medicine, and Theology. So we find that the engineering curricula have the responsibility for the full and broad education of those students choosing engineering as a career.

This must include responsibility for social and humanistic instructions as well as for it in science and engineering. The professional schools which can demand a preliminary college period of study such as pre-law, premedicine, are freed from such requirements. Thus, we begin to sense the responsibility of the engineering faculty.

For at least the past two decades, various engineering educational leaders have recommended that, as a solution to this very real dilemma, curricula leading to the Bachelor's degree in engineering be lengthened from four to five years. But it is financially and economically difficult on both school and student, particularly the latter, to lengthen the four-year course that has for so long been the norm. A number of schools have experimented with this proposal, but it has never been generally accepted. Such five-year trials as were in operation at the beginning of our entry in World War II were nearly all abandoned due to the pressure of urgent war programs. Now with the post-war policies developing one can expect with assurance that this manner of solution will be tried again. Today we find Minnesota, Ohio State, and Cornell announcing the adoption for five-year curricula in engineering with no shorter alternative offered, at least to non-veterans. The engineering educational world will watch with keen interest the response to the five-year curricula ventures of these leading engineering schools.

World War II has, of course, tremendously underscored the need for the training in citizenship, social responsibility and leadership along with the technological training for all engineers. Adequate attention to social-humanistic needs must be given.

Training in English to insure that young engineering graduates have the ability to express themselves in a clear, concise manner is being demanded with increasing emphasis. The advances in special technologies have been so varied, rapid, and extensive that coverage of special technologies is now impossible. These advances, further, require sound fundamental knowledge for their understanding and successful study in later years, either in post-graduate work or in industrial practice. Because of these urgencies in varied fields of general education, the philosophy underlying engineering education is today being based more and more on a broadening of the base of engineering education in which strong emphasis is placed on fundamentals, rigorous instruction in the use of English, and inclusion of a well-planned social-humanistic stem.

Since these bases are common to the needs of all engineering curricula, it has been possible in many instances to create a curriculum that is uniform for all engineering students for the first year. As the desirability for the universality of basic instruction in all engineering curricula has increased, it has been possible to extend this curricular uniformity well into the second and even to an appreciable extent into the third year. Beyond the philosophical justification for this trend, it further offers practical advantages to both student and faculty. It allows the

student a longer period of engineering acquaintanceship prior to his making his vocational choice, and through simplification of instruction it eases the administrative burden of the faculty. While I cannot at the moment accept the extent to which I have recently heard this trend proposed, I have found in several widely separated instances the suggestion that out of a four-year program leading to the Bachelor's degree in a designated engineering branch the first three years be totally uniform.

Because of the impact of World War II, the report of the Committee on Aims and Scope of Engineering Curricula was re-submitted for study to a committee on Engineering Education after the War, appointed in 1943. This was also under the chairmanship of H. P. Hammond. This committee was "directed specifically to study the need, as made clear by the issues of war, of creating among engineers an understanding of the social and economic world they live in and have so large a share in creating."

This committee re-substantiated the report of the earlier committee on Aims and Scope adding to it special emphasis on social responsibility and suggesting that undergraduate engineering training should be developed for three groups of students: (1) those who would follow engineering programs for the usual pattern, (2) those preparing for jobs in the operation and management of industries, and (3) those who would be fitted for unusual scientific and creative accomplishments. The committee report gives detailed suggestions concerning means for achieving these educational objectives. It was this report that recommended not less than 20 per cent of the student's educational time be devoted to the humanistic-social stem.

A second problem that resulted from the tremendous growth in higher education since 1893 has been the large numbers of students seeking a four-year engineering education who might better be served by a short program that prepares men with the practical techniques of particular occupations or industries. This leads to the urgent need, as yet almost totally unmet in the United States, for Technical Institutes. It is noted that in Great Britain, in the Soviet Union, and in pre-war Germany such a program was carried out on a far greater scale than anything yet developed here. In the U.S.S.R. in 1938 it was reported that there were 3,400 technical institutions with an enrollment of 700,000 students. It is most desirable that the engineering colleges take a leading part in the development and guidance of this form of institution during its rise. Time does not permit me to elaborate this need further, but it is among the most pressing now facing engineering educators, and it will continue to receive increasing attention. The growth of this form of technical instruction is one development in the general field of engineering education that can be predicted with certainty.

One major function, essential to engineering education, has yet been unmentioned. Dean Hammond, while reviewing the past in engineering education at the time of the 50th anniversary of the founding of the S.P.E.E., said, "In engineering research, the record of development of the past fifty years had not, on the whole, been as satisfactory as it has in instruction. There has never been accorded to research in engineering in this country anything approaching the support

which has been accorded to research in agriculture; nor has engineering research in educational institutions approached in magnitude or importance similar research in industry. Most of the research that has been done has been confined to a score of institutes. This one great phase of the work of engineering educational institutions which should complement other phases, needs greatly to be strengthened and supported." Speaking on the same program, President Karl Compton of M.I.T. said, "Our engineering education has not been as productive in developing the research side as it has in developing the side of the practical application of the most conventional arts. . . . I don't know how important this research side is to the engineer, but it is very important to society that attention be given it. If it is not given by the engineer, it will be given by other groups; it will be given always by scientists."

The growth of research in engineering institutions is essential to the further effectiveness and maturity of engineering education. The programs of research in engineering schools must be integrated with the educational program and is recommended in the report of the committee on Engineering Education after the War, particularly for those students who plan to undertake graduate work.

In reviewing current trends in engineering education, several other items are prominent. I can only quickly enumerate them here. One is the increase in the attention to individuals or small groups. Tendencies in this direction are noted with increasing frequency. There will also be an increase in part-time graduate work by young graduate engineers' who are in industry and who attend colleges located in industrial centers. Those schools not favorably located in relation to industries will match this by increasing numbers of industrial fellowships and research programs closely allied with industrial problems.

Turning for a moment to the social-humanistic stem, the conclusion seems that it should be taught as a parallel development with the science and engineering sequence rather than departmentalized without relationship to its associate studies, or given solely during the earlier and more immature years of student study.

One trend which appears now, being greatly accelerated by war research experience and one which I believe will be sharply developed, is the lessening of sharp administrative divisions that departmentalize faculties. There will be an increasing interrelationship between department faculties where, for example, a physics professor will teach in electrical and chemical engineering; a thermodynamist will cut across department lines by teaching in mechanical and chemical engineering and in physics. Many other possible examples can be quickly visualized. Such a program has been in effect with considerable success for many years in the organization of Columbia College's course in Contemporary Civilization. Recently M.I.T. announced a new method of research technique in terms of groups wherein men from various departments, for example a metallurgist, a physicist, and a physical-chemist from their respective departments, join with a group of chemical engineers to undertake more effectively work on research problems. Such associations will of necessity be loosely formed, dissolving and reforming new associations as needs arise. I feel confident similar groups will de-

velop in our teaching methods and produce greater teaching effectiveness.

Lastly, I would say a few words concerning recommendations of the Planning Committee of the Engineering School of the North Carolina State College.

Because of economic factors, we do not favor the extension of those curricula leading to the Bachelor's degree from four to five years. Four-year curricula in basic engineering divisions leading to the degree of Bachelor of Designated Engineering are to be retained.

Thorough training in English composition is to be given. The efficiency of this training shall be determined by an achievement test given to the student at the end of the junior year. Those showing need for additional instruction shall be given this during the senior year.

Emphasis is to be given to fundamental knowledge and total hour requirements, in terms of quarter hours, have been lessened from an average of 240 to 225 to permit the added time required by this phase of the program.

Forty-two hours are to be devoted to a newly organized social-humanistic stem. This will include in the Freshman year nine hours of Composition and a second nine hours devoted to studies on the Rise of Western Civilization. This latter gamut will serve as an introduction to the remaining twenty-four hours of the stem that are to be given in the subsequent three years. Parallel development with our science-technology stem is insured by spacing these hours evenly throughout the upper three years. These hours shall be devoted to an election of not fewer than two nor more that three fields chosen from the following: Literature, Economics, History and Government, Ethics and Philosophy, and Sociology. Limited individuality in course program is permitted through eighteen hours of additional electives in the upper two years.

Opportunity for advanced study is recommended through two types of graduate programs, each of one year's length and each leading to a Master's degree. One, leading to the Master of Science degree, is developed with a strong emphasis on research and is offered primarily to those who wish to enter this type of life work and who may wish to continue through the Doctorate. The second is a Master of Specified Engineering program that is considered terminal and requires less research but gives greater emphasis on course work. This program is designed for men wishing to enter industry.

The research activity of the engineering school is being stimulated through the Department of Engineering Research, which has been created by a reorganization of the former Engineering Experiment Station. It is the function of the Department to assist and encourage faculty members with their research interests by offering them opportunities of association with problems brought to the school by outside agencies. These agencies may be state or federal government units, technical or industrial associations, or private companies or individuals. Integration between research problems and student instruction is realized by having student participation in these problems, either through fellowships or by hourly wage agreements. The Department also provides assistance to those faculty members who wish to engage in fundamental research for which no outside support is available.

We appreciate that we have not solved all problems. Further, we know that some of our decisions, which to us appear as successful solutions, would not be of equal use to others because of differences in situations or state needs. Yet we feel that we have stepped forward. We look to those about us who are engaged in similar endeavors and from you we hope to learn further and trust that we may, in turn, be of some value to those of you who look to us. We believe we are together trying to aid and be aided in our unending task of the furtherance of engineering education. We have confidence in our collective ability to meet the challenges of the day.

Southeastern Section, A.S.E.E.

The Speed Scientific School of the University of Louisville was host to the Southeastern Section of A.S.E.E. and the Research Branch of the Section at their thirteenth annual meeting on April 17–18–19, 1947. Nineteen of the twenty-two colleges in the Section and three industrial organizations were represented by the ninety members attending.

The meeting of the Research Division was held on April 17. Reports from all the colleges in the Section showed a surprising increase in research activities since the research branch was begun in 1944. All of the colleges reported plans for still further increases for the coming year.

Harry Diamond spoke on "Miniaturization of Electronic Circuits." Great advances had been made in research on this project, he said, by the miniaturization of electronic tubes and by painting the circuit on a plastic background.

The theme of the first meeting of the Section on the morning of April 18 was, Getting Back to Normalcy.

R. R. Slaymaker described the method of limiting enrollment at the Case School of Applied Science by the use of the Pre-Engineering Inventory tests used in combination with special tests prepared at the Case School. Through the use of these tests, he said, the number of failures have been decreased to one per cent.

James L. McAuliffe of the University of Tennessee spoke on The Influence and Progress of the War Veteran on the Campus. His talk was based on his experience with the veterans on the campus at the University of Tennessee where he found that the veterans, after being on the campus for one term, were a highly vocal and progressive group and in general had a sobering influence on the campus. They were more sensitive to opportunities, carried on better discussion in classes and increased the social activities of the campus on a lower cost level. Dr. McAuliffe said that he felt that in many ways the veteran was a definite contribution to campus life. He pointed out, however, that, judging from the veterans, the army was a poor place for physical development or education.

In talking to the section on the subject, Modification and Trends in Engineering Curricula, William G. Van Note of N. C. State College gave a brief resume of the history of the development of the engineering curricula in the United States. The present trends he said were as follows:

(1) Tendency to make the first three years of the five curricula uniform.

(2) An increase of above 20 per cent of Social Humanistic items in all curricula.

(3) Building up interest in Engineering Research which at present is not so great as industrial research.

(4) Tendency toward greater specialization especially in graduate curricula.

R. D. Span, of the Alabama Polytechnic Institute, speaking from his own experience on the Values of Humanistic Social Courses in Engineering Curricula, said that something should be done to get the student out of the deep valley of not understanding human beings around him. The Humanistic courses, he felt, should be planned to take hold of the mind of the student as a part of his engineering course. The courses should be given in the early part of his course so they would be of advantage to him in dealing with other students and the instructors in the advanced work.

The theme of the afternoon session was, Keeping Pace with the Times. The principal speaker for this session was Harry Diamond who spoke on The Status of Engineering Research in Electronics.

Dr. Diamond pointed out that the oversold public, the lack of trained personnel and the retarded rate of progress in pure science were problems beyond the control of the research engineer.

Points brought out in his paper were as follows:

1. The emphasis on engineering research during the war has advanced our knowledge of materials, design technique and instrumentation.

2. There is no lack of fundamental principles on which to base engineering research.

3. There is much need for accelerated research to meet the demands of society. This can be supplied by redoubling our present efforts.

4. We must rely in a great measure on the pure scientist to bridge the gap between fundamental knowledge and engineering application.

W. G. Ireson of Virginia Polytechnic Institute spoke on The Improvement of Class Room Instruction. He believes class room instruction is influenced by four factors: the teacher, the student, the facilities and the subject. A teacher, he said, should be selected on the basis of his personality, ability to express himself well, and his knowledge of the subject to be taught. Too often we select the teacher who has great knowledge of the subject but who cannot impart the knowledge because of a lack of personality or self expression. Too many students, he said, are enrolled in engineering schools who are not properly equipped to do the work. We must be more careful in the selection of our students. The use of class room aids not only helps the student but saves the teacher time in getting the subject across. Finally, he pointed out, that in teaching any subject it is necessary to correlate that subject to other subjects taken by the student and to the student's background knowledge.

Frank G. Slack of Vanderbilt University, speaking on Atomic Energy and the Atomic Age, pointed out that there should be a greater interest shown by the colleges in the work of the Atomic Energy Commission by sending representatives of their faculty to take the courses of study offered at the Atomic Energy plants. Research in Atomic Energy, he said, was growing by leaps and bounds and that now the new found elements and the radio active isotopes were being extensively used in many fields of science and medicine.

Henry N. Lyons, Administrative Manager of Laboratories for the Devoe Reynolds Co. of Louisville, spoke on Shortcomings of the Present Graduates as Diagnosed by an Industrialist. The

recent graduates, he said, have received adequate training in the fundamentals of the engineering course they elected in college but they generally lack a practical working knowledge of mathematics and an appreciation of the importance of a knowledge of fundamental business principles. He considered mathematics, especially calculus and differential equations, a most valuable tool in the hands of the engineer. The colleges, he believes, should do something about this mathematical shortcoming. In the matter of the lack of knowledge of business, he said, there is little the engineering college can do in a crowded four year curriculum other than to stimulate interest in the subject by short courses.

W. N. Cox, of Georgia School of Technology, speaking on Safety Engineering in Engineering Curricula, described the course as offered at the Georgia School of Technology and stated that he thought there was a need and a place for safety engineering courses in all engineering curricula and especially in those related closely to industry.

A forum on the subject, Teacher Shortages, was held at the last session on the morning of April 19th with four speakers participating,

R. O. Shots of the University of Alabama gave the historical background of the causes of teacher shortages.

I. A. Trively, speaking on Industrial Opportunities Vs. Those of Teaching, pointed out that we could not hope to attract the good men from industry until we gave them adequate pay and adequate facilities with which to work.

R. E. Shaver, speaking on Effects on Staff Morale, said that he believed that the quality of man now in the engineering colleges would turn in a good job in spite of an overload. Since this is a temporary condition we should be glad to carry on since we now have the kind of students we have all been waiting for.

O. W. Stephenson of Tulane University, speaking on Some Avenues of Hope, said that the teacher shortage had taught us several things. One was the fact that we needed more laboratory equipment so that the student could do more work by himself. In this way one teacher could handle more men in the laboratory. This could be carried into the class room too. With better instructional aids one instructor could teach more students at one time.

At the conclusion of this final session a short business meeting was held. It was decided that the meeting for the spring of 1948 would be held in Gainesville, Florida, the University of Florida as host institution. Appropriate resolutions were passed thanking the Speed Scientific School for their wonderful hospitality.

The following officers were elected for the next year.

Chairman: Fred J. Lewis of Vanderbilt University.

Vice-Chairman: J. E. Hannum of Alabama Polytechnic Institute.

Member of Council: Leo. Jos. Lassalle of Louisiana State University.

Secretary: H. Gale Haynes, The Citadel.

Second International Conference on Soil Mechanics and Foundation Engineering

The Second International Conference on Soil Mechanics and Foundation Engineering will be held in Rotterdam, Holland, in June 1948. This meeting, sponsored by the Netherlands Government, is a resumption of the series initiated at Harvard University in 1936 and interrupted by the war. The president of the Conference is Karl Terzaghi, Consulting Engineer and Professor of Engineering Practice at Harvard University. The Conference is being organized by J. P. Van Bruggen, Director of Public Works, Rotterdam, T. K. Huizinga, Director of the Laboratory of Soil Mechanics in Delft, and other Dutch engineers. The Conference will be conducted in the English language.

In the United States, a National Committee on Soil Mechanics, consisting of thirty-five outstanding foundation engineers and soil mechanics experts representing professional engineering societies and governmental engineering organizations, has been formed. Philip C. Rutledge, Professor of Civil Engineering at Northwestern University, is chairman of the Committee. Its official address is: U. S. National Committee on Soil Mechanics, the Technological Institute, Northwestern University, Evanston, Illinois. To insure adequate representation of the United States in the technical works of the Conference, the National Committee has been divided into fifteen subcommittees covering the major technical subdivisions of Soil Mechanics and Foundation Engineering.

Prospective members of the Conference and authors of papers are requested to notify the National Committee of their intentions as soon as possible. To meet the conditions set up by the Dutch organizing committee, authors of papers to be published in the first volume of Proceedings of the Conference must submit in triplicate to the National Committee a title and brief (250 word) description of each paper prior to September 1, 1947. For this volume completed papers must be received by the National Committee by December 1, 1947.

Organized travel for those attending the Conference is planned and will be arranged by the National Committee. Complete information on the Conference can be obtained by writing to the U. S. National Committee on Soil Mechanics.

Publication of a new "Directory of Member Institutions and Review of Current Research" was announced by the Engineering College Research Council of the A.S.E.E. at the Annual Meeting in Minneapolis, where first copies of the new bulletin were distributed.

The major publications activity of the Research Council last spring, the new Directory lists the directors and research officers, gives a brief statement of research policies, personnel, and expenditures, and lists research projects now active in various divisions of each member institution.

An extensive free distribution of the Directory has just been completed by the Research Council, including a large number of federal and industrial research laboratories. Libraries of all member institutions of the Research Council have received copies. While the supply lasts, additional copies are available at $1.00 each from the Secretary of the Research Council, John I. Mattill, The State University of Iowa, Iowa City, Iowa.

College Notes

Douglas F. Miner has been appointed Director of the Division of Student Personnel and Welfare at the **Carnegie Institute of Technology.** In accepting his new appointment, Dr. Miner has resigned as George Westinghouse Professor of Engineering, a post which he has held since September 1938.

Case Institute of Technology (formerly Case School of Applied Science). T. Keith Glennan, now an executive of Ansco Division of General Aniline & Film Corporation, Binghampton, N. Y., and wartime director of the U. S. Navy Underwater Sound Laboratory, has been appointed president of Case Institute of Technology. Mr. Glennan will be the first business executive to head the Cleveland engineering school, which has had but three presidents since its establishment 67 years ago as Case School of Applied Science and which is adopting its new name on July 1st. He succeeds Dr. William E. Wickenden * who retires on September 1st, after 18 years of service.

The **Texas A. & M. Research Foundation** formally inaugurated service of the newest alternating current network calculator laboratory at College Station, Texas, on June 27, although the first study was actually begun on June 2. Leading engineers of the several companies who cooperated in establishing this laboratory were present to inspect the calculator and review preliminary plans for their respective studies.

* Died September 1, 1947.

Manufactured by the Westinghouse Electric Corporation, the Texas A. & M. calculator has a total of 18 generating units and 344 circuits, and is one of the largest ever constructed. It is the first to include several unique features such as pi-circuits to represent long transmission lines, and an auxiliary potential that may be used as a reference voltage on the instruments. The calculator is also equipped with two master control and instrument desks with the circuits so arranged that it will be possible to study two systems simultaneously. The use of the second control desk will permit instruction of and research by graduate students without interfering with studies by utility companies.

A-c network calculators have, for the most part, been used by electric utility companies in the study of load flows, short circuit analysis, stability problems, etc. Since all other physical systems, e.g., mechanical and hydraulic, have electrical analogies, the use of a network calculator is not limited entirely to electrical systems. The Texas A. & M. Research Foundation also plans to add accessory equipment which will extend use of this calculator to the study of traveling wave transients and other phenomena.†

† "The Network Calculator Brought Up to Date," H. A. Travers, *Westinghouse Engineer,* July, 1944.

"Today's Network Calculators Will Plan Tomorrow's Systems," Dan Braymer, *Electrical World,* January 5, 1946.

"Mechanical Problems Solved Electrically," G. D. McCann & H. E. Criner, *Westinghouse Engineer,* March, 1946.

The Texas A. & M. network calculator is installed in Bolton Hall, the Electrical Engineering Building, on the campus of the Agricultural and Mechanical College of Texas. The Research Foundation is a non-profit corporation organized so as to use the facilities of the College in research that will contribute to state and national development. The calculator laboratory is under the direct supervision of Lewis M. Haupt, Professor of Electrical Engineering, with R. D. Chenoweth assisting. Both have had previous experience on the Westinghouse network calculator at East Pittsburgh, Pennsylvania.

The companies who cooperated in establishing this laboratory are: Central Power and Light Company, Community Public Service Company, Dallas Power and Light Company, El Paso Electric Comany, Gulf States Utilities Company, Lower Colorado River Authority, Southwestern Gas and Electric Company, Texas Electric Service Company, Texas Power and Light Company, West Texas Utilities Company, and Westinghouse Electric Corporation.

Sections and Branches

University of Colorado Branch. Members of the University of Colorado Branch held a meeting in January to elect new officers. This was the first meeting since the University went on a war-time basis. Succeeding W. Otto Birk, as Chairman, and W. S. Nyland, as Secretary, are Arthur J. McNair and William Brubaker. Professor Birk still remains the chairman of the Rocky Mountain division, and he is arranging a meeting of the Sections in Wyoming and Colorado to be held in Boulder sometime in April.

A second meeting of the Colorado section was held on March 2, with the N.R.O.T.C. officers in charge of the program. Captain C. A. Fine gave a talk on the history of aviation, illustrated with several movies.

The 11th annual meeting of the **Pacific Northwest Section** was held at the State College of Washington on May 9 and 10, 1947.

Friday afternoon was used for registration, inspection of the State College of Washington's laboratories and getting acquainted.

At 7:00 P.M., the annual banquet was held in the Home Economics Building. After the usual good dinner, W. A. Pearl, acting as toastmaster, introduced Dean Royal Sloan, who welcomed the guests to the State College of Washington and to Pullman. Following the welcoming, talks were given by E. R. Wilcox of the University of Washington, and F. W. Candee of the State College of Washington on their experiences at Shrivenham and Biarritz, Both had interesting reports of their activities at those schools in our first effort at "G.I." education. Ending the formal program on a lighter vein, Scotty Aplchall, a magician of Pullman, entertained with a magic act. A long period of visiting and getting acquainted followed.

The Saturday morning technical meeting was called to order by Chairman Candee, who introduced Homer J. Dana, who presided over the morning session. Due to his efficient handling,

the meeting moved at good speed. The topic for the first meeting was "Post War Engineering Education—Present Problems and Future Plans." Talks were given by representatives of each school and many interesting and revealing points were brought out by each speaker. The discussion following showed that a great deal of interest had been aroused in the audience. Talks were given by:

G. W. Gleeson, Oregon State College.
B. T. McMinn, University of Washington.
W. W. Tinniswood, University of Idaho.
C. A. Arents, Montana State College.
S. P. Spielman, Montana School of Mines.
J. G. McGivern, Gonzaga University.
S. T. Stephenson, Washington State.

After a brief intermission, a paper was given by W. A. Pearl, recently appointed Director of the Institute of Technology of Washington State College, on the subject "The Cooperative System in Engineering Education." Dr. Pearl spoke from his experiences in helping set up such a system at Illinois Institute of Technology. Again the discussion following showed the interest of the audience, particularly in the possibilities of cooperative systems in northwest schools.

Oregon State College presented an invitation to hold the 1948 convention at Corvallis, Oregon, and the invitation was accepted. Following the usual custom, the officers for the coming year are all from Oregon State College and are:

Chairman, A. L. Albert,
Vice Chairman, W. H. Paul,
Secretary-Treasurer, M. P. Coopey.

After lunch at the Home Economics dining room, the afternoon session opened with a report on the 1946 Surveying Conference by F. W. Welch of Washington State College. He told of the history of the conferences and invited everyone interested to attend the 1947 conference to be held at Washington State's Summer Surveying Camp in the Snoqualmie National Forest near Naches. Washington.

Following Mr. Welch's report the meeting broke up into departmental meetings for discussion of individual department problems. Sessions were held for:

Mechanical Engineering—D. E. Aldrich, Chairman.
Electrical Engineering—O. E. Osburn, Chairman.
Civil Engineering—L. B. Almy, Chairman.
General and Administration—R. D. Sloan, Chairman.

Respectfully submitted,

L. B. Almy,
Secretary-Treasurer

The annual meeting of the **Rocky Mountain Section** was held at the University of Colorado on Saturday, May 10 1947. The conference was held in the Engineering Administration building, with all schools of the section represented—University of Wyoming, University of Denver, Colorado A. & M. College, Colorado School of Mines, and the University of Colorado. Over one hundred members and guests attended the sessions. The program, which was arranged by Professor Arthur J. McNair, chairman of the host branch, was as follows:

10:00 A.M. Morning Session:
Call to order by Arthur J. McNair, Secretary.
Greeting from Dean C. L. Eckel, College of Engineering, University of Colorado.

A Word of Welcome—Robert L. Stearns, President, University of Colorado.

10:30 A.M. "The Aim and Scope of a General Economics Course for Engineers" by James E. Dugan, Assistant Professor of Economics, University of Colorado.

Discussion.

11:15 A.M. Dean N. A. Christensen, College of Engineering, Colorado A. & M. College, Presiding.

"The Electrical Engineering Curriculum" by V. O. Long, Associate Professor of Electrical Engineering, University of Wyoming.

Discussion by Fred H. McClain, Professor and Chairman of Electrical Engineering, University of Denver.

Afternoon Session

2:30 P.M. Dean R. D. Goodrich, College of Engineering, University of Wyoming, Presiding.

"Laying a Professional Foundation in the Freshman Year" by Robert L. Lewis, Professor and Head of Department, and Robert H. Dodds, Associate Professor of Civil Engineering, Colorado A. & M. College.

Discussion.

3:15 P.M. Dean C. M. Knudson, College of Engineering, University of Denver, Presiding.

"The Relation of Laboratory Investigational Problems to Field Applications" by George W. LeMaire, Assistant Professor of Petroleum Refining Engineering, Colorado School of Mines.

Discussion.

3:40 P.M. "Chemistry in the Mineral Industries" by Robert A. Baxter, Associate Professor of Chemistry and of Fuel and Gas Engineering, Colorado School of Mines.

Discussion.

After a noon luncheon meeting, the members and their guests made a tour of the various laboratories, shops, and classrooms, which were open for inspection. The tour was followed by a business meeting. As the Section had not met since 1942, considerable reorganization was required. Professor J. T. Strate was elected chairman and Professor Robert H. Dodds secretary for the year 1947–48. The Section gladly accepted the invitation of the Colorado A. & M. College to meet at Fort Collins next year.

The following resolution was presented and accepted by the Section:

"Be it resolved: that the Presiding Chairman request the members of the Rocky Mountain Section, American Society for Engineering Education, in annual meeting assembled May 10, 1947, to rise and stand for a moment in silent memory of:

John C. Fitterer (of School of Mines)
Allan S. McMaster (of University of Colorado)

whose fellowship and friendly counsel in this group we find sorely missing. Be it further resolved: that the Secretary of the Section be instructed to prepare a notification of this action and transmit it to the surviving next-of-kin of these gentlemen."

In conjunction with the A.S.E.E. meetings, the student chapters of the American Society of Civil Engineers from the foregoing schools held their regional conference, the first since 1942. Thus an opportunity was given for many of the students and faculty

to travel to Boulder together and become better acquainted. At the close of the A.S.E.E. conference, members of the Civil Engineering faculties of the various schools joined the students in a beefsteak fry on Flagstaff Mountain.

ARTHUR J. MCNAIR,
Secretary

Mineral Technology

RESOLUTION

WHEREAS, God in His infinite wisdom has taken away Thomas Thornton Read, former Vinton Professor of Mining Engineering at Columbia University, and a faithful and devoted member and former officer of the Mineral Engineering Division of the American Society for Engineering Education, and

WHEREAS, he was the leading and most active exponent of the importance of engineering training for the mineral industries, as was evidenced not only by his effective teaching and personal relationships with his students, but also by his prolific writings which included: "Careers in the Mineral Industries," "Our Mineral Civilization," and "The Development of Mineral Industry Engineering Education in the United States,"

Now WE, the officers and members of the Mineral Engineering Division of the American Society for Engineering Education, assembled in the annual meeting of the Division at Minneapolis, Minnesota,

By these Resolutions, do express our sadness at the passing of our distinguished co-worker and beloved friend, and

We direct that a copy of these resolutions be sent to the bereaved family and spread in the Minutes of the Division.

Minneapolis, Minnesota
June 20, 1947

MEMBERS ELECTED AT JUNE 1947 MEETING

ALLEN, GEORGE H., Instructor in Graphics, Massachusetts Institute of Technology, Cambridge, Mass. J. T. Rule, D. P Adams.

ALLEN, STUART C., Assistant Professor of Engineering Drawing, Champlain College, Plattsburgh, N. Y.

AMES, ALFRED C, Assistant Professor of English, Illinois Institute of Technology, Chicago, Ill. J. C. Peebles, W. C. Krathwohl.

AMRINE, HAROLD T., Assistant Professor of Industrial Engineering, Purdue University, Lafayette, Ind.

ANDERSON, ALVIN G., Instructor in Civil Engineering, University of Minnesota, Minneapolis, Minn. L. F. Boon, A. S. Cutler.

AXTELL, OLIVER, Instructor in Chemical Engineering, University of Maine, Orono, Maine.

BABCOCK, HENRY A., Instructor in Civil Engineering, Colorado School of Mines, Golden, Colorado.

BACHRACH, WILLIAM, Director of Education, Chicago Technical College, Chicago, Ill.

BAKER, JOHN L., Assistant Professor of Mathematics, University of Cincinnati, Cincinnati, Ohio.

BAKER, OLLIE J., Director, Low-Cost Housing Research, Louisiana State University, Baton Rouge, La.

BAZANT, ZDENEK, Associate Professor of Civil Engineering, Technical University of Prague, Prahall, Karlovonam, 1F, Czechoslovakia.

Bergelin, Olaf P., Associate Professor of Chemical Engineering, University of Delaware, Newark, Del.

Bishop, Myron C., Associate Professor of Engineering, Evansville College, Evansville, Ind.

Bliesner, Gustov H., Assistant Professor of Physical Science, Farragut College and Technical Institute, Farragut, Idaho.

Bodman, Elmer P., Assistant Professor of Mechanical Engineering, University of Cincinnati, Cincinnati, Ohio.

Borri, Robert, Instructor in General Engineering Drawing, University of Illinois, Urbana, Ill.

Boyd, Gilbert W., Associate Professor of Metallurgical Engineering, Michigan College of Mining and Technology, Houghton, Mich.

Buell, Arthur W., Instructor in Petroleum Production Engineering, Colorado School of Mines, Golden, Colo.

Cannon, Irving, Dean of Pre-Engineering, Associated Colleges of Upper New York, Champlain College, Plattsburgh, N. Y.

Carlson, C. I., Acting Chairman, General Engineering Drawing, University of Illinois, Navy Pier, Chicago, Ill.

Carroll, Frank T., Instructor in Mechanical Engineering, Louisiana State University, Baton Rouge, La.

Cassinis, Gino, Directore del Politechinco di Milano, Milan, Italy.

Chase, Howard W., Assistant Professor of Shop Practices, State College of Washington, Pullman, Wash.

Clark, Andrew G., Head, Dept. of Mathematics, Colorado A. & M. College, Ft. Collins, Colo.

Claybaugh, Howard S., Division Engineer in the Drainage Dept., Armco Drainage and Metal Prod. Inc., 4345 Lyndale Ave. N., Minneapolis, Minn. B. J. Robertson, T. E. Murphy.

Collins, H. John, Chadwick Professor of Civil and Municipal Engineering, University College, University of London, Gower Street, London, England.

Cramer, Paul, Assistant Professor of Mathematics and Engineering, Monmouth College, Monmouth, Ill.

Cummings, Jerry W., Head, Department of Aerodynamics, The Aeronautical University, Chicago, Ill.

Cunningham, Charles A., Associate Professor of Mathematics, Youngstown College, Youngstown, Ohio.

Davis, Royal E., Instructor in Physics, University of Detroit, Detroit, Mich.

Davis, S. J., Dean, Kings College, Strand, W. C. 2, London, England.

Driscoll, George F., Instructor in Civil Engineering, University of Notre Dame, Notre Dame, Ind.

Dumke, Walter H., Assistant Professor of Chemistry, Colorado School of Mines, Golden, Colo.

Easton, Clarence W., Assistant Professor of Pre-Engineering, Champlain College, Plattsburg, N. Y.

Euker, Engelund, Director, Tekniske Hojskole of Denmark, Copenhagen, Denmark.

Eyrolles, Marc, Director, Ecole Speciale des Travaux Publics du Batiment et de l'Industrie, 61 Boulevard St. Germain, Paris, France.

Faye-Hansen, K. M., Rector, Institute of Technology, Trundheim, Norway.

Fenn, Fred H., Professor of Engineering Mechanics, Louisiana State University, Baton Rouge, La.

Ferrara, Guido, Instructor in Electrical Engineering, University of Detroit, Detroit, Mich.

Findlay, James E., Instructor in General Engineering Drawing, University of Illinois, Navy Pier, Chicago, Ill.

Fossum, Guilford O., Assistant Professor of Civil Engineering, University of North Dakota, Grand Forks, N. D.

Furgerson, Lynn D., Instructor in Mathematics, East Central Junior College, Decatur, Miss. D. M. McCain, H. C. Simrall.

Gerster, Jack A., Assistant Professor of Chemical Engineering, University of Delaware, Newark, Del.

Gillette, Edward C., Jr., Professor of Physics and Chemistry, U. S. Military Academy, West Point, N. Y. B. W. Bartlett, R. I. Heindein.

Gould, Gilbert B., Instructor in Electrical Engineering, University of New Hampshire, Durham, N. H.

Green, Robert S., Assistant Professor of Industrial Engineering, The Ohio State University, Columbus, Ohio. C. E. MacQuigg, P. N. Lehoczky.

Guess, Robert H., Instructor in Physics, Electricity and Radio, Copian-Lincoln Junior College, Wesson, Miss. D. M. McCain, A. G. Holmes.

HANSEN, HOWARD J., Associate Professor of Civil Engineering, University of Florida, Gainesville, Fla.

HARDER, KEITH C., Head, Science Education, Scientific Personnel Division, Office of Naval Research, Navy Department, 4213 28th Street, Mt. Rainier, Md.

HARMON, DANIEL L., Director, Department of Physics, University of Detroit, Detroit, Mich.

HARTUNG, WALTER M., Vice-president, Director of Training, Academy of Aeronautics, LaGuardia Field, New York, N. Y.

HEBEL, IVAN L., Professor of Mathematics, Colorado School of Mines, Golden, Colo.

HERRMANN, R. R., Manager, Rate and Sales Research, Northern States Power Company, 15 South Fifth Street, Minneapolis, Minn. B. J. Robertson, T. E. Murphy.

HILL, G. T. R., Professor, University College, Gower Street, London, W.C. 1, England.

HIRSH, FRED, Assistant Research Engineer, University of Florida, Gainesville, Fla.

HOGUE, WALTER R., Assistant Professor of Civil Engineering, University of Santa Clara, Santa Clara, Calif.

HOLLADAY, DEE M., Instructor in General Engineering Drawing, University of Illinois, Navy Pier, Chicago, Ill.

HOSSIER, KARL G. N., Rektor, Chalmers University of Technology, Gotenborg (Gothenburg), Sweden.

HOWARD, J. H., Director, Business and Technical Personnel, Eastman Kodak Company, 37 Stoneham Drive, Rochester, N. Y. E. M. Billings, H. S. Gardner.

HOWE, ROBERT T., Instructor in Mathematics, University of Cincinnati, Cincinnati, Ohio.

HUMMER, J. L., Instructor in Electrical Engineering, Rhode Island State College, Kingston, R. I.

HUYDTZ, L. H. M., Professor, Technische Hogesschool, Kanalwee 26, Delft, Holland.

IHLEFELD, WILLIAM G., Professor, Head, Department of Safety Engineering and Education, University of Puerto Rico, Rio Piedras, Puerto Rico.

JOHNSON, A. E., Instructor in Graphics, Massachusetts Institute of Technology, Cambridge, Mass. J. T. Rule, D. P. Adams.

JOHNSON, HERMAN J., Instructor in Physics, University of Illinois, Navy Pier, Chicago, Ill.

JOHNSON, JUSTIN O., Instructor in Mechanical Engineering, University of Maine, Orono, Maine. H. D. Watson, W. S. Evans.

KEILY, H. HAROLD, Assistant Professor in English, University of Colorado, Boulder, Colo.

KING, IRA L., Assistant Professor of Industrial Engineering, University of Florida, Gainesville, Florida. J. Weil, N. C. Ebaugh.

KINTZER, NICHOLAS D., Dept. Head, Design Department, Academy of Aeronautics, 336 Coolidge Street, W. Hempstead, N. Y. A. Stott, K. L. Burroughs.

KOCH, REUBEN, Instructor in Mathematics, University of Cincinnati, Cincinnati, Ohio.

KUNESH, JOSEPH F., Senior Professor of Engineering, University of Hawaii, Honolulu, T. H.

LARSON, SIDNEY C., Associate Professor of Electrical Engineering, University of Minnesota, Minneapolis, Minn.

LAVES, WALTER C., Deputy Director General UNESCO, 19 Avenue Kleber, Paris, France.

LEMAIRE, GEORGE W., Assistant Professor of Petroleum Refining, Colorado School of Mines, Golden, Colo.

LIBBEY, WALDO M., Instructor in Electrical Engineering, University of Maine, Orono, Maine.

LOEBS, WILLIAM F., Instructor in Physics, University of Detroit, Detroit, Mich.

LONGHOUSE, ALFRED D., Professor and Head, Department of Agricultural Engineering, West Virginia University, Morgantown, W. Va.

LYON, DANIEL R., Mechanical Engineer, Construction Department, International Harvester Company, 180 N. Michigan, Chicago, Ill.

LYON, GEORGE B., Instructor in Civil Engineering, University of Minnesota, Minneapolis, Minn.

MAJUMDA, MANOJKUMAR, Architect and Civil Engineer, Shilpa Bitan, P. O. Rehabari, Dirugarh, Assam. F. L. Bishop, N. McKenry.

MANSON, PHILIP W., Associate Professor of Agricultural Engineering, University of Minnesota, University Farm, St. Paul, Minn.

McCrocklin, Andrew J. J., Assistant Professor of Electrical Engineering, University of Texas, Austin, Texas.

McDonald, Clarence T., Instructor in General Engineering Drawing, University of Illinois, Navy Pier, Chicago, Ill.

Melville, Thomas J., Chief Instructor in Refrigeration, Milwaukee School of Engineering, Milwaukee, Wis. S. A. Eng, C. O. Werwath.

Miekle, G. Stanley, Director, Research Relation with Industry, Research Director, Purdue Research Foundation, Purdue University, Lafayette, Ind.

Mikulaschek, W., Librarian, Bibliotheque de l'Ecole Polytechnique Federale, Service de Documentation, Wartstrasse 14, Zurich 7, Switzerland.

Moid, Howard P., Staff, Industrial Relations Dept., Mead Corporation, Chillicothe, Ohio. E. W. Johnson, A. O. Lee.

Molina, Edward C., Special Lecturer in Mathematics, Newark College of Engineering, 141 Dodd Street, East Orange, New Jersey.

Morey, Leslie G., Vice President, Chicago Technical College, 2000 S. Michigan Avenue, Chicago, Ill.

Mulligan, James E., Professor of Electrical Engineering, Worcester Polytechnic Institute, Worcester, Mass.

Murphy, John H., Professor and Head, Law Department, Milwaukee School of Engineering, Milwaukee, Wis.

Murray, William M., Associate Professor of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Myers, Edwin D., Assistant Professor of Civil Engineering, Mississippi State College, State College, Miss.

Noren, Oscar B., Instructor in Engineering Drawing, University of Detroit, Detroit, Mich.

Oberzil, Edward W., Instructor in Engineering Drawing Dept., Case Institute of Technology, Cleveland, Ohio. O. M. Stone, W. E. Nudd.

O'Meara, Stanley R., Dean of Students, Bridgeport Engineering Institute, 25 Palm Street, Bridgeport, Conn.

Osthues, B. Bradley, Associate Professor and Head of Engineering Drawing Department, Sampson College, Sampson, N. Y.

Otto, Carl E., Associate Professor of Chemistry, University of Maine, Orono, Maine.

Parke, Edward C., Instructor in Engineering, University of Redlands, Redlands, Calif. D. L. Soltau, F. L. Bishop.

Parkinson, Harold N., Instructor in General Engineering, Oregon State College, Corvallis, Ore.

Parsons, Kenneth L., Assistant Professor of Electrical Engineering, University of Maine, Orono, Maine.

Peirce, Eugene W., Chief, College Relations Department, Western Electric Company, Chicago 23, Ill.

Peterson, George E., Assistant Professor of Mechanical Engineering, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

Petrie, Raymond W., Instructor in Mechanical Engineering, Pratt Institute, Brooklyn, N. Y.

Pippard, A. J. S., Professor, Imperial College of Science and Technology, South Kensington, London, S. W. 7, England.

Pitkin, Emerson S. B., Assistant Professor of Pre-Engineering, Champlain College, Plattsburg, N. Y.

Powers, Maston L., Vice Director of Engineering Extension, Oklahoma A. & M. College, Stillwater, Okla.

Price, Rupert M., Assistant Professor of Physics, University of Illinois, Navy Pier, Chicago, Ill.

Purintun, Theo., College Textbook Representative, John Wiley and Sons, De Smet, S. D.

Restemeyer, William E., Assistant Professor of Mathematics, University of Cincinnati, Cincinnati, Ohio. R. A. Anderegg, H. K. Justice.

Reza, Fazlollah, Assistant Professor, Teheran University, Iran; 520 W. 122 Street, New York, N. Y.

Riordan, Frank S., Instructor in Chemical Engineering, University of Tennessee, Norris, Tenn. R. M. Boarts, R. W. Morton.

Roberts, Robert C., Dean and Science Instructor, East Central Junior College, Decatur, Miss. D. M. McCain, H. C. Simrall.

Rushing, James F., Instructor in Engineering Drawing, Missouri School of Mines and Metallurgy, Rolla, Mo.

SABOTT, FREDERICK K., Instructor in Chemistry, Colorado School of Mines, Golden, Colo.

SCHERMERHORN, JAMES R., Assistant Professor of Engineering Drawing, University of Illinois, Navy Pier, Chicago, Ill.

SEARS, JAMES F., Professor and Head of Physics Department, Evansville College, Evansville, Ind.

SEYMOUR, RAYMOND B., Director, Research Institute, Industrial Research Institute, Chattanooga, Tenn.

SHEA, HERMAN J., Associate Professor of Surveying, Massachusetts Institute of Technology, Cambridge, Mass.

SMETANA, JAN, Professor of Engineering, Dean of the Faculty of Civil Engineering, Charles University, Trojanova 13, Praha II, Czechoslovakia. J. S. Thompson, C. G. Benjamin.

SMITH, CARL E., President, Cleveland Institute of Radio Electronics, Cleveland, Ohio.

SMITH, HOWARD M., Assistant Professor of Electrical Engineering, University of Vermont, Burlington, Vt. E. R. McKee, R. O. Buchanan.

SMITH, STEELE B., Instructor in General Engineering Drawing, University of Illinois, Navy Pier, Chicago, Ill.

SMITH, THOMAS C., Assistant Professor of Electrical Engineering and Mathematics, Youngstown College, Youngstown, Ohio.

SMITH, WILLIAM P., Resident Dean of Pre-Engineering, Sampson College, Sampson, N. Y.

STOLPER, EDWIN F., Instructor in Engineering Mechanics, New York University, New York, N. Y.

SUMRALL, MARGARET, Head, Mathematics Dept., Sunflower Junior College, Moorhead, Miss. D. M. McCain, L. L. Patterson.

SWEET, ISRAEL, Instructor in English, Pratt Institute, Brooklyn, N. Y.

VAN EE POEL P., Dean, Faculty of Applied Sciences, University of Brussels, Brussels, Belgium.

VAN DUZEE, GERALD R., Associate Professor of Chemical Engineering, Wayne University, Detroit, Mich.

VERNON, J. REXFORD, Assistant Secretary and Sales Promotion Manager, Johnson Service Company, 507 E. Michigan Street, Milwaukee, Wis. C. O. Werwath, S. A. Eng.

WALLACE, WAYNE P., Associate Professor of Civil Engineering, Louisiana State University, Baton Rouge, La.

WELLS, EDWARD H., Assistant Professor of Pre-Engineering, Champlain College, Plattsburg, N. Y.

WHITNEY, ROY P., Professor and Acting Head of Chemical Engineering, University of Maine, Orono, Maine.

WITHAM, WALTER H., Instructor in Charge of Mechanical Engineering Shops, University of Maine, Orono, Maine.

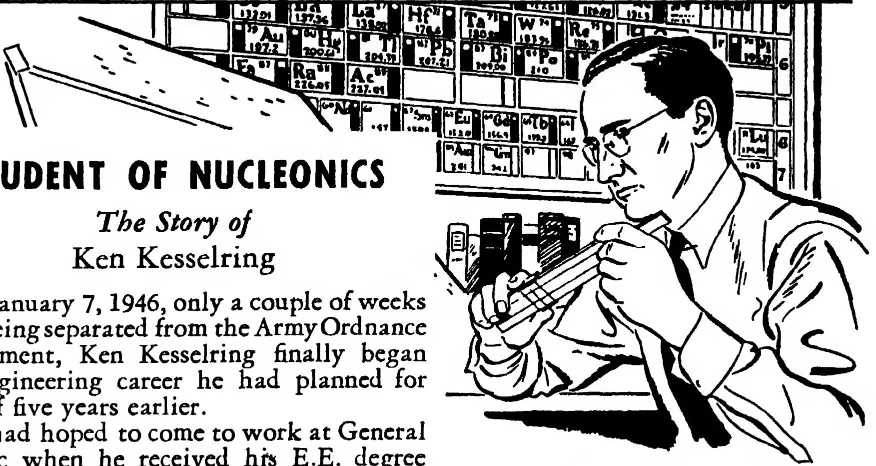
WOODBURY, MARY A., Librarian, Milwaukee School of Engineering, Milwaukee, Wis. C. O. Werwath, S. A. Eng.

WOXEN, R., President, The Royal Institute of Sweden, Director of Technology, Stockholm, Sweden.

WYART, JEAN, Professeur a la Faculte des Sciences, Universite de Paris, 1 Rue Victor Cousin, Paris, France.

ZERBY, ALTON B., Executive Secretary, Eta Kappa Nu Association, P. O. Drawer C, Dillsburg, Pa. N. S. Hibshman, W. H. H. Cowles.

Campus to GENERAL ELECTRIC



STUDENT OF NUCLEONICS

The Story of
Ken Kesselring

On January 7, 1946, only a couple of weeks after being separated from the Army Ordnance Department, Ken Kesselring finally began the engineering career he had planned for himself five years earlier.

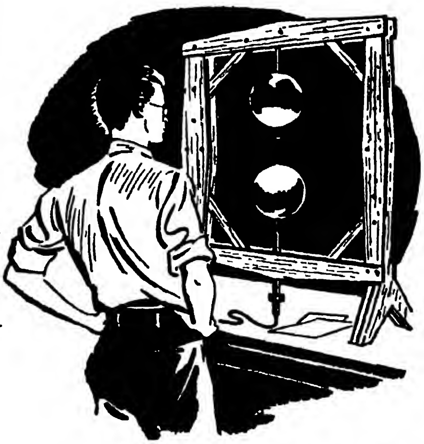
He had hoped to come to work at General Electric when he received his E.E. degree from Cornell in 1941. Instead he had gone into Ordnance as a second lieutenant.

There he worked with the Research and Development Center at Aberdeen Proving Ground, with "Kangaroo"—the group formed to introduce new weapons into combat outfits—and with the Ordnance Technical Intelligence Group assigned to study Nazi weapons and engineering developments.

At G.E. he entered the Rotating Engineering Program—especially set up to give the returning veteran a period of familiarization and general orientation. Upon completing his assignments under the program, Ken was assigned to the General Electric Atomic Power Engineering Project and is today a section head and project engineer of the Design Group. The objective: the harnessing of atomic energy for power development and generation.

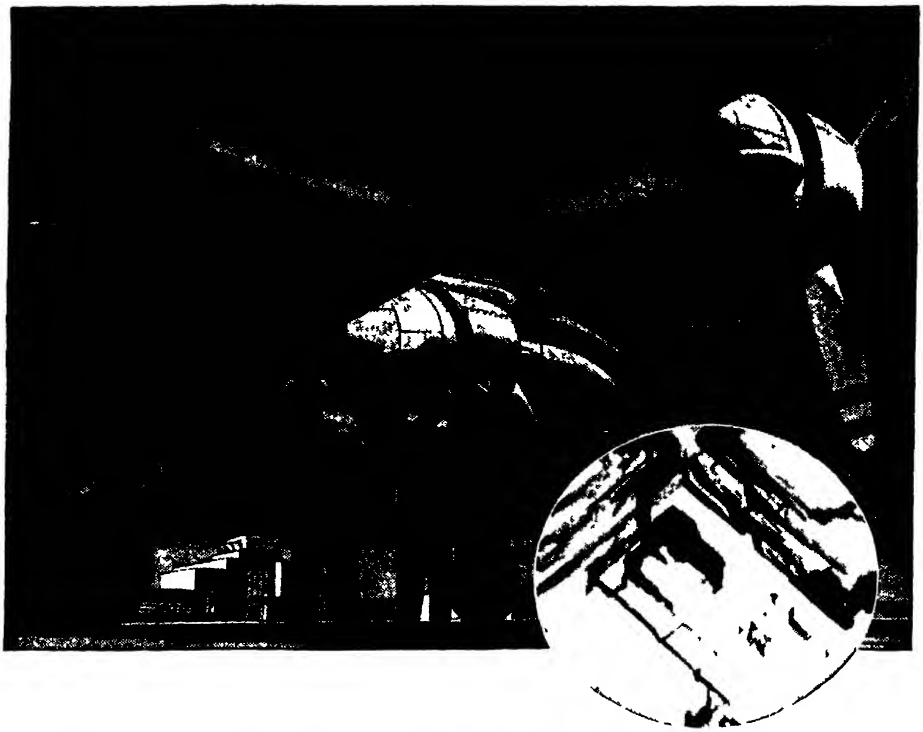
For your copy of "Careers in the Electrical Industry," write to Dept. 237-6, General Electric Co., Schenectady, N. Y.

Out of the Army less than two years, Ken is already heading up a design group connected with the G-E Atomic Power Engineering Project.



At Cornell, Ken studied power engineering, specializing in high-voltage protective equipment. He graduated first in his class in 1941.

GENERAL ELECTRIC



WHAT PART OF A PLANE IS THIS?

Clue: 31,700 would cover a pinhead

It is part of the wing surface . . . an area so microscopic that 31,700 spots like this would barely cover a pinhead.

You are looking at aluminum through an electron microscope, the way Alcoa Research scientists look at aluminum alloys in our laboratories. They get down to aluminum's *really* fine points . . . explore among the atoms.

Studying structures like this is one of the ways Alcoa metallurgists learn how to improve aluminum alloys and how to make new ones. By scientific experimentation they combine with aluminum the *right* amounts of the *right* metals to produce the results they want . . . alloys as strong or stronger than structural steel, at one-third the weight . . . alloys that make better castings, forgings, extrusions . . . alloys for innumerable uses.

You wouldn't hear half, *not even a hundredth* as much about aluminum today if it weren't for these alloys that Alcoa Research has produced. Aluminum's great and growing usefulness springs directly from their development. Nature made aluminum light. Alcoa has made it strong and versatile and low in cost.

ALUMINUM COMPANY OF AMERICA. Gulf Bldg., Pittsburgh 19, Pa.

MORE people want MORE aluminum for MORE uses than ever

ALCOA FIRST IN **ALUMINUM**

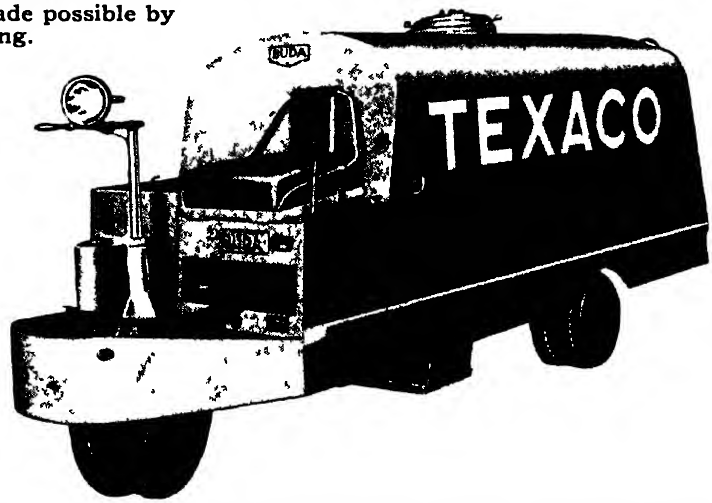
A worthwhile future for young engineers

THE Buda Company has long used arc welding as an economical and weight-reducing method in the fabrication and assembly of industrial shop truck frames and chassis, railroad tool parts, sheet metal engine housings and many other products. Arc welding's flexibility and durability has aided the development of many new Buda products. The airplane refueler illustrated would have been impractical except for welding.

Arc welding is a modern production method that offers a worthwhile future to young, carefully trained engineers.

President
The Buda Company, Harvey, Illinois

Buda "Chore Boy" Airplane Refueler—a new design made possible by arc welding.



Published through the courtesy of The Lincoln Electric Company, Cleveland 1, Ohio

56th Annual Meeting

American Society for Engineering Education

UNIVERSITY OF TEXAS
AUSTIN, TEXAS

June 14 - 18, 1948

THE JOURNAL OF ENGINEERING EDUCATION

VOLUME 38 NUMBER 2

Contents for October, 1947

THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION
OFFICERS 1947–48

President

CHARLES E. MACQUIGG, The Ohio State University, Columbus 10, Ohio

Vice President, 2 years

(In charge of general and regional activities)

B. J. ROBERTSON, University of Minnesota, Minneapolis, Minn.

Vice President, 1 year

(In charge of instructional division activities)

C. J. FREUND, University of Detroit, Detroit, Mich.

Vice President, 2 years

(Engineering College Administrative Council)

S. S. STEINBERG, University of Maryland, College Park, Md.

Vice President, 1 year

(Engineering College Research Council)

F. M. DAWSON, State University of Iowa, Iowa City, Iowa

Secretary

ARTHUR B. BRONWELL, Northwestern University, Evanston, Ill.

Treasurer

J. S. THOMPSON, McGraw-Hill Book Co., New York 18, N. Y.

Assistant Secretary

NELL MCKENRY, Northwestern University, Evanston, Ill.

Headquarters

NORTHWESTERN UNIVERSITY, Evanston, Ill.

56th Annual Meeting

AUSTIN, TEXAS, June 14-18, 1948

Host

UNIVERSITY OF TEXAS

Other WILEY books on page 6

A. B. Bronwell, Secretary

On October 1, 1947, the office of secretary of the A.S E.E was moved to Northwestern University where Professor Arthur Bronwell assumed the post of secretary formerly held by Dr. F. L. Bishop. Professor Bronwell has been on the faculty of Northwestern University since 1937, where he holds the rank of Professor of Electrical Engineering. A product of the Illinois Institute of Technology, he received the B.S degree in 1933 and M.S. degree in 1936. Additional graduate work in engineering was taken at the University of Michigan and he recently received an M.B.A degree for work in business administration taken at Northwestern University. His engineering career started in 1930 when he was employed as an operator in substations of the Commonwealth Edison Company, working nights while attending school days. After graduation, he spent two years on a program of re-evaluation of the fixed capital assets of the Commonwealth Edison Company He was then appointed to the faculty of Northwestern University. During the summer of 1941, Professor Bronwell was employed as a special project engineer by the Bell Telephone Laboratories. At the outbreak of the war, he organized and supervised an Army Signal Corps school at Northwestern University for the training of radio and radar engineers. From 1943 to 1945, he supervised a radar research project at Northwestern University in cooperation with the M.I.T. Radiation Laboratory and Galvin Manufacturing Company. He has served as consultant to Galvin Manufacturing Company, DuMont Company, and others. He is author (with R. E. Beam) of a text on "Theory and Application of Microwaves" and numerous technical papers at Northwestern University he was chairman of a Committee on Faculty Salaries.

Professor Bronwell served as Chairman of the Electrical Engineering Division of the A.S.E.E. and member of the General Council in 1946–47. He also served on an A.S.E.E. committee for the preparation of a teaching manual. He is a member of the American Institute of Electrical Engineers, Institute of Radio Engineers, Sigma Xi, Eta Kappa Nu, and is President of the National Electronics Conference for 1947.

Minutes of the 55th Annual Meeting, A.S.E.E.

The 55th annual meeting of The American Society for Engineering Education was held at the University of Minnesota, June 18-23, 1947. Over 1,300 members and guests were registered. Four general sessions and twenty-six conferences were held. Huber O. Croft, Professor and Head, Department of Mechanical Engineering, The State University of Iowa, President of the Society, presided.

The first general session was opened by Vice President E. B. Norris who introduced Dean S. C. Lind of the University of Minnesota who welcomed the Society to the city and also presented a gavel to the President. President Croft delivered the presidential address, Education for an Atomic Age. T. C. R. Fox, Professor of Chemical Engineering at Cambridge University, England, spoke of the new plan which is being put into operation there. Brig. General John M. Devine told of the University Military Training Experimental Unit at Fort Knox; M. M. Boring presented the report of the Committee on Manpower; and W. N. Jones presented the report of the Committee on Undergraduate Curricula.

The second general session was presided over by J. R. Killian, Jr., President of the Administrative Council. The following program was presented: International Relations of Engineering Education by N. J. Padelford; report of the Committee on Transfer of Students from Emergency Colleges by H. P. Hammond, Chairman; and the report of the Committee on Salary Survey of Engineering Schools by D. C. Jackson, Chairman.

The Thursday evening program was devoted to a meeting with our international visitors. Addresses were delivered by President Croft; Miroslav Jiranek, University of Praha, Czechoslovakia; D. N. Kowshick, Department of Education, India; Rodrigo Flores, University of Chile; A. E. Flynn, University of Nova Scotia; J. S. Thompson and L. G. Straub who had visited foreign countries recently.

The third general session was opened by Vice President C. J. Freund who introduced the Chairman of the Division on Humanistic-Social Studies, E. S. Burdell. The following papers were presented: What Every Engineer Should Know by W. B. Embler; May the Teacher of Literature Help? by A. M. Buchan; American Destiny and Engineering Motivation by A. E. Avey.

The annual dinner was held Friday evening with President Croft presiding. Addresses were delivered by S. C. Lind, Dean of Engineering at the University of Minnesota, and L. M. Gould, President of Carleton College. The Lamme medal was given to Warren K. Lewis, Yale University, and the George Westinghouse Award to B. R. Teare, Carnegie Institute of Technology. The Nominating Committee reported the following for officers. Upon motion they were duly elected:

For President for one year: Charles E. MacQuigg, The Ohio State University.

For Vice President for two years:

B. J. Robertson, University of Minnesota (responsible for general and regional activities).

C. J. Freund, University of Detroit continues in office as Vice President for one year.

For Treasurer for one year: James S. Thompson, McGraw-Hill Book Co.

Previous to this, the Administrative Council had elected S. S. Steinberg, University of Maryland, President for two years. F. M. Dawson, State University of Iowa, continues in office as President of the Research Council for one year.

REPORT OF THE COMMITTEE ON THE SECRETARIAT

By W. E. WICKENDEN, *Chairman*

It is related that one of our lesser colleges invited that august figure, Dean Briggs of Harvard, to give a graduation address. Being gratified by his acceptance, they decided to refurbish the college chapel and revarnish the seats and the pulpit furniture. This was in the days before the drying power of infra red light was fully understood. Unfortunately, hot and muggy weather led to reluctant drying on the part of the varnished furniture, so when the speaker of the graduation exercises was announced, there was a sinister sound of peeling and ripping as his academic costume came loose from the chair, but the dean arose and met the situation with perfect self-possession and aplomb, saying, "Ladies and Gentlemen, it had been my intention to bring you a plain, unvarnished tale."

If the first part of my remarks is to be a plain and unvarnished tale, I shall make it a short tale. It is regrettable that it is an unfinished tale.

We are faced with a crisis due to the retirement from the secretaryship of Dr. Bishop. President Croft, on coming into office, appointed a committee consisting of Dean Dawson, President Doherty, Dean Freund, President Heald, and the speaker as Chairman to give its best consideration of this problem. We began by preparing a job analysis of the secretaryship on the modern tripartite basis of organization and we supplemented this by certain conclusions. First, it would be a great advantage and a substantial economy to the Society to continue its association with one of our centrally located engineering schools. Secondly, that the location should be conveniently accessible by rail, air and motor to as large a proportion of our membership as possible. It should be in an urban and university center, affording adequate accommodations for group meetings and conferences of substantial size. Thirdly, both the administrative load within the Society and the rapidly growing load of liaison relationships with professional, industrial, educational and governmental agencies make it desirable to move as rapidly as possible toward a full time secretarial service.

Next, after reviewing the existing sources of income and probable expenses of our now enlarged organization with the executive committee and taking into account the retirement provisions in view for the secretary and the assistant secretary, it seemed apparent that the present dues of the Society would not suffice to sustain a full time secretary and to provide for the necessary assistance and overhead expense.

The committee felt it advisable to proceed in a provincial manner pend-

ing the possible change in dues and further instruction from the executive committee. It did, however, make a new study of the distribution of our membership and of its geographical center, in order to ascertain the most convenient region for the Society's headquarters. The center of gravity of our membership was found to lie within a triangle bounded by Ann Arbor, Columbus and Cleveland. The committee thereupon decided to canvass the major institutions in the urban centers within this area and in a peripheral zone including Chicago (you Chicagoans may not like that), Cincinnati, and Pittsburgh, to ascertain which institution would be able and willing to provide headquarters for the Society and what individual the executive officers of this institution would recommend as a possibility for an appointment as a secretary, initially on a part time basis if necessary, but with the understanding that the goal in view was a full time engagement.

Of the institutions approached, the University of Michigan, Northwestern, Illinois Institute, and Pittsburgh and Case indicated their willingness to provide secretarial headquarters and suggested in all eight possible candidates for appointment.

In the meantime, our executive committee had inaugurated a canvass of the membership on the question of an increase of dues and pending these returns has been unable to give our committee instruction and a budget having to do with secretarial salary and expense. While it might have been possible to approach some of the candidates suggested on a purely elastic basis of part time service subject to later adjustment, the strong desire that had been expressed by certain of the officers of the society and members of the committee seemed to make it unwise to approach any candidate until our special committee and the executive committee had been able to confer together on all aspects of the situation and this conference was arranged for Wednesday morning of this convention week.

Meeting together at this time, the two committees agreed first to maintain the secretary's office, if possible, in connection with one of the institutions within the region previously canvassed; secondly, to appoint a secretary on an initial basis of approximately two-thirds time service, that is, leaving open the possibility of his carrying half load academic engagement, at a salary making the position attractive to a young man of excellent ability in the intermediate academic or administrative ranks of our colleges; and third, to select if possible an appointee who has had an active record of participation in the Society's affairs, and who can be counted upon to continue and upbuild the record of widely decentralized activity, rather than to build up a highly centralized plan of operations. Finally, in order to assure immediate steps to carry out these measures, the executive committee agreed to relieve the present chairman of the special committee of that responsibility, as it will not be possible for me to give active service in the early part of the summer and I am happy to announce that the chairmanship of the committee has passed into the highly capable hands of our good friend, President Heald of the Illinois Institute of Technology. Active measures will be taken as quickly as possible to carry out the general policy herein indicated. That part is the plain, unvarnished tale.

The rest, I trust, has a little more romance and color. All of you have heard the oft-repeated classic that every great institution is but the lengthened shadow of a man, and to that many of us can testify from long association with this Society. I recall being stopped one time upon the street corner by the Dean and Nestor of all of us, old Professor C. Frank Allen, one of the founders of the Society, I believe its first secretary, who in my early teaching days told me he had observed that the young men in engineering education who were likely to go far were those who took an active part and interest in this great organization. After a long period of association with the Society from the most junior of its ranks to now one of the older guard, I can testify through intimate association to the aptness of this classic expression as it relates to our retiring secretary. The shadow of a man—unobtrusive, but inseparable from every interest of the Society. Silent most of the time, but knowing everything, and never getting between any man or this great institution and the sun.

Now I don't know with what illusions Fred Bishop may have begun his service as Secretary 33 years ago, whether hopes of increased income or fame may have led him on, but I am certain of one thing that he has continued through all these years at a constantly increasing sacrifice of time and comfort and I suspect of financial income as well. It is just that spirit of self-dedication that makes the annals of education glorious and has created such an irresistible appeal to men of high spirit, and on this occasion of his retirement I should like to move that this Society spread on its minutes the following testimonial to Frederic Lendall Bishop:

FREDERIC LENDALL BISHOP

The American Society for Engineering Education, on the occasion of your retirement from the office of Secretary after thirty-three years of devoted service, desires to express to you its deep gratitude and enduring affection.

UNDER YOUR WISE BUT SELF-EFFACING GUIDANCE, the Society has attained to a commanding influence in the realms of higher education and professional endeavor. As a common forum for the problems of instruction, administration and research, it has rendered a notable service to teachers and colleges alike. It has united those who guide, teach and inspire students of engineering in a fraternal bond rarely equalled and never surpassed.

CEASELESS FIDELITY, unvarying loyalty to worthy goals and sound standards, a progressive spirit, concern for the welfare of students, devotion to freedom for teacher and school, and resourcefulness in achieving great ends with modest means . . . these have been the personal hall-marks of your administration.

YOU HAVE BECOME A TRADITION among us, worthy of the high place of honor and affection in which we shall always hold you.

On behalf of the Society

HUBERT O. CROFT
President

June 20, 1947

On behalf of the Society, and to be signed by its President, I move, Mr. President, that we engross this resolution of testimonial upon our minutes and present it to our retiring Secretary.

SECRETARY BISHOP: Mr. President, this is kind of a bad position to be in. I should have studied more sociology and very much less science—I can see that now.

Of course, it has been a great pleasure to be Secretary of this organization. The friendships have been remarkable. The Secretary's office, you know, operates through Miss McKenry. Don't you get any idea that I do the work, or even create the ideas. At the time I took over the Secretary's work, among other things, the Society for the first time appropriated $40 a month for clerical and editorial assistance.

Well, it is going to be a tough job to find a new Secretary that will do as much as the present group does—I know that. Of course, while the committee is looking around, Miss McKenry will carry on. Right now I wish that would extend over a long time. I thank you one and all. (Dr. Bishop was presented with a silver tea service, various pieces of which were prsented by Webster Jones, Dean Earle, Dean Hammond, Dean Ferguson, Dean Potter, and Dr. Jackson.)

The fourth general session was presided over by F. M. Dawson, President of the Research Council. The following program was presented: Synopsis of the Annual Report of the President, F. M. Dawson; report of the Committee on Federal Research Agencies by Thorndike Saville; report of the Committee on Legislation by Thorndike Saville; report on Senate Bill 493 by E. B. Norris; Physiological Problems Encountered in Engineering by Philip Drinker; Research Problems and Opportunities in the Field of Jet Propulsion by S. F. Duncan; Research in Turbulent Flow by J. S. McNown.

The following resolution was presented and accepted by a rising vote:

We, the members and guests of The American Society for Engineering Education, wish to thank our host, the University of Minnesota, for the leadership, cooperation, and friendliness that have made this 55th annual meeting an outstanding success. We are especially grateful to President J. L. Morrill; to Dean S. C. Lind and his Faculty in the Institute of Technology; to the genial, patient, and helpful Chairman of the General Local Committee, Professor B. J. Robertson, and to the Chairmen and members of his many committees.

We are grateful also to the Convention Bureau of the Chamber of Commerce for assisting the local committee; to the Minnesota Hotel Association for arranging reservations; and to the Nicollet Hotel for providing us space for headquarters and meetings.

For the gracious hospitality provided for the ladies attending the meeting, we express our appreciation to Mrs. H. E. Hartig and the members of her committee.

Since we think that our various programs have been particularly interesting and stimulating, we wish to thank our speakers, our officers, and all the committees representing the divisions and special conferences.

Inasmuch as this is the last meeting under the guidance of our able secre-

tary, Dr. F. L. Bishop, we wish to reeognize here his long and faithful service and his many contributions to engineering education and to the outstanding growth and prestige of this Society.

WE RESOLVE, THEREFORE: That this expression of our gratitude and appreciation be recorded in the minutes of the meeting and be duly conveyed to all those herein mentioned.

(signed) L. O. STEWART,
Iowa State College,
S. S. STEINBERG,
University of Maryland,
W. T. ALEXANDER,
Northeastern University,
W.O. BIRK,
University of Colorado, *Chairman.*

The meeting adjourned sine die to meet at the University of Texas, Austin, Texas, June 14–18, 1948.

Minutes of Couucil Meeting, June 18, 1947

Present: H. O. Croft, H. W. Barlow, W. O. Birk, F. L. Bishop, A. B. Bronwell, E. S. Burdell, L. E. Conrad, H. A. Dangel, C. L. Dawes, F. M. Dawson, H. L. Dodge, W. R. Dumble, C. D. Fawcett, C. J. Freund, T. C. Hanson, E. D. Howe, J. R. Killian, R. C. Kinter, J. H. Lampe, W. M. Lansford, L. S. Letellier, S. C. Lind, H. J. McIntyre, D. F. Miner, G. Murphy, E. B. Norris, O. N. Olson, G. K. Palsgrove, B. J. Robertson, H. S. Rogers, S. S. Steinberg, J. S. Thompson, A. W. Turner, H. W. Wood, W. R. Woolrich, J. H. Zant.

The report of the auditor was read and accepted as the report of the Treasurer. It was ordered printed.

President Croft presented the following report:

A retiring president's address is easy to deliver but difficult to compose. For of necessity it must be a hodgepodge made up of an expression of thanks to those who have helped, an annual statement to the stockholders, an explanation to those few who have disagreed with policies adopted, a brief sermon looking toward the future, and a sigh of relief for the completion of a job.

This is the end of the first year of operation of the American Socity for Engineering Education under the new constitution adopted by you a year ago at St. Louis. During the transition I doubt if many of you have noted any change in that comfortable feeling you experienced from your membership in the Society for the Promotion of Engineering Education. In fact there has been little change. You, the General Council, are now more representative of the Society as a whole, and the engineering college administrators and the engineering college research directors have the autonomy necessary to act quickly when the time element is essential.

For example, the Engineering College Research Council has been more than influential in having engineering research finally included in the Research Foundation Bill now pending before Congress. Engineering research had been expressly omitted in the original bill submitted for hearings. I wish here to express my congratulations to E.C.R.C. for this real accomplishment. Again I wish to express my sincere thanks to Dean F. M. Dawson, President of E.C.R.C., and his executive committee for the sympathetic and complete cooperation they have given during the past year.

Likewise, the Engineering College Administrative Council under the leadership of President Killian has been helpful in its advice and generous in its cooperation. It was at the suggestion of E.C.A.C. that the Report on Academic Tenure was sent, after the approval of Council, to all presidents of engineering institutions. It should also be noted that their committee on military training is studying very carefully the proposed legislative program for compulsory military training.

Vice Presidents Freund and Norris have worked hard and long on much of the detail work that has been carried on for the proper functioning of the Society. We owe them much and I wish to offer them the thanks of the Society.

We are likewise particularly grateful to those of you who worked on the Membership Committee. You have made an all time record in new memberships. You have enrolled 887 new members this year which makes a total membership of 4,592 at this time, plus 165 institutional members, bringing the total to 4,757. This is the largest membership the Society has ever had. Let all of us welcome these new members and help them to understand why our group is unique.

The only matter that has been undertaken this year which seemed to be in the least controversial was the ballot on the increase in membership dues. The real controversy was not as to whether an increase in dues was justified, but rather what form the increase should take, whether it should be a blanket increase for all or a graduated increase according to rank. This matter was presented first to the executive committee and then to Council. The ballot submitted to you was the one approved by most of the members of Council. I am delighted to report that 1,989 ballots had been received up to midnight on June 14th. Of these 1,492 or 74 per cent, were in the affirmative; 487, or 25 per cent, were negative; and 10, or 1 per cent, were disqualified either because they were not marked, because they were not signed, or because they could not be interpreted. Since the constitution provides that the majority of the ballots received shall determine the issue, all of us will be billed at the new rate for annual dues next July 1st—grades under associate professor, $5.50; associate professor, $6.00; all others, $7.00.

I wish to express the gratitude of the whole Society for the outstanding work of our 36 committees and their chairmen. You can judge the excellence of the work they have done in the fifty or more sessions they are producing here for our benefit.

One of the most satisfying experiences of my life has been that as your representative on the First National Advisory Committee of UNESCO, the United Nations Educational, Scientific and Cultural Organization. This group, authorized by Congress, is one of many similar bodies working in most of the member Nations of the United Nations to promote peace, good will and mutual understanding between the peoples of the world. What UNESCO lacks in budget is compensated for at least partially by the sincere enthusiasm of the members. All of us hope, I am sure, that UNESCO will succeed in its fundamental objectives.

It was through the inspiration of UNESCO that I took the liberty of asking the State Department to send an invitation through each of their consular offices to each country with whom we maintain diplomatic relations. This invitation to attend this meeting here in Minneapolis was extended to a prominent engineering educator in each country. The first approach was made to the State Department in December but for various reasons the invitations were not sent to the consular offices abroad until April. Dr. Dowdell of the University of Minnesota was asked to be the liaison official here for all foreign guests. He advises me this morning

that 20 guests from foreign shores are among us this morning. It seems to me that invitations to our colleagues abroad and one session of the annual meeting during which our guests may discuss their problems with us should be an annual tradition. This is one way we may really contribute to international appreciation and understanding.

As many of you know, F. L. Bishop, a member since 1907 and after serving this Society faithfully and well as Secretary for 33 years, retires in July from his academic activities at the University of Pittsburgh and likewise from his leadership of this Society. It is difficult for me to express those thoughts of appreciation which are in the hearts of all of the older men in the Society. The history of this society has been made in no small part by the imagination, by the planning, and by the devotion of Dr. Bishop. Under Dr. Bishop the membership has grown from about 1,300 to 4,800. Many Presidents have served under him and all of them have finished that service with a deep appreciation of his insight into the strange actions of man, his keen sense of humor, his inherent sense of justice, and his absolute reliability. He has been an inspiration to me as he has to all of his friends in the Society. The Society will be fortunate to say the least if it can obtain a successor who even partially will fill his shoes. We wish Dr. Bishop a happy and fruitful future for the free days that are now his.

Miss McKenry, who has served the Society for the same length of time as Dr. Bishop, has been priceless in the performance of her duties. Without her the President would have been lost in a fog during the past year. To her I offer my sincere gratitude and likewise a personal apology for the many sins I have committed.

I have tried to analyze for my own satisfaction what is inherent in this Society that draws us together once a year to dicsuss almost the same material year after year and I have come to the conclusion that it is the aggregation of great men who gather at this meeting, men who are following in the footsteps of Baker, Allen, Jackson, Talbot, Raymond, Marston, Ketchum, Cooley and Sackett, to mention but a few. Men comparable to these are here now if you but look about you, and fail not to search particularly in the younger group of men if you wish inspiration and stimulation. It must be the deep personal friendships that are ripened over the years that really bring us back to this annual meeting and only incidentally does the public discussion of our common problems really justify our presence. I suspect that there are fewer cliques, regional, functional, or political, in this society than most, and it is your responsibility to maintain this characteristic of our unique society.

The Secretary's report was accepted and ordered printed.

The report of Vice President E. B. Norris on Sections was accepted and recommendations therein left for action by the next Vice President (B. J. Robertson).

Life membership was conferred upon W. C. Ebaugh, W. H. Kenerson, R. A. Porter, R. E. Root.

Sub-committee of the Comittee on Relations with Industry:

Committee on Ethics of Personnel Interviews and Practice: M. M. Boring, C. E. MacQuigg, J. C. McKeon, A. A. Potter. The report is to be sent

to the new President and he should appoint a committee to study further the present code of ethics.

W. E. Wickenden reported on secretariat. (See report made at annual dinner.)

H. S. Rogers appointed as representative on Engineers' Council for Professional Development.

W. E. Wickenden appointed as representative on American Council on Education.

W. R Woolrich invited the Society to meet at the University of Texas, Austin, Texas, in 1948. This invitation was accepted and Monday noon June 14 to Friday noon June 18 were the dates set.

A revision of the present Constitution and By-Laws was referred to the Committee on Constitution.

One hundred and eleven new members were elected, making a total of 887 new members for 1946–47, the largest number in the history of the Society. We now have 4,592 individual and 165 institional members, a total of 4,757 members.

Report of the Committee on Manpower*

By M. M. BORING, *Chairman,*
General Electric Company

I must report to you that this can only be considered as an interim report. There are a number of factors involving the manpower problem that have come up making it necessary for us to continue the study of the problem in order to give you a complete report which, we hope, will be accurate.

I am not going to bore you with a stream of figures, but will give you a few pertinent facts at this time. We could, I suppose, sum up the entire report by saying there is going to be more, soon.

Last summer in July, at the time the so-called Compton Report was made by Karl Compton, we had a great deal of guess work in connection with the enrollment and also in my opinion some guess work in connection with the demand side of this important problem.

After enrollment was completed in September, 1946, of last year's group, Mr. Armsby, in Washington, a member of our Committee, made a complete and very accurate study of the actual enrollment of the technical students in the country. I will give you the total results of that study.

His study indicated 92,600 freshmen, 57,500 sophomores, 33,800 juniors, 23,400 seniors and 800 fifth year men in the engineering colleges. We find 14,900 students unclassified, who clearly are candidates for degrees in this period of time. Assuming the same rate of admission, we used last year's rate—this factor must be studied. Some of the schools are still in session and we do not have an accurate figure of admission under the present situation so we are going back to last year's assumption which is the only basis on which we can, at the moment, make our studies—the study would indicate the senior class of 1947 was 23,000, the class of 1948 will graduate 31,000, the class of 1949 should graduate 36,000 and in the class of 1950 there will be 58,000 students.

Another important study, which was missed completely in last year's report, was the number of young men in the other colleges who anticipate transferring. We do not refer to those boys in the Government temporary pre-engineering schools, but to those in colleges such as arts and other types of institutions. Mr. Armsby again took on the job of surveying that group. He contacted over 1,100 such institutions and has replies from roughly 900, which indicates we have in these schools, who expect to transfer this coming year or in the next two years, an additional 77,000 boys, of whom we estimate 55,000 will enter freshman classes in engineering and 22,000 will enter other classes—sophomore, junior or senior as the case may be.

* Presented at the 55th Annual Meeting, A.S.E.E., Minneapolis, June 18–21, 1947.

We believe that we are faced in 1951 with an even higher admission than we would normally use, and there will be another group of 54,000 in that particular class who will be thrown on the market.

I would like to say, and I am sure I speak for every member of the Committee, we do not think this is quite as serious a situation as was first believed. It means that it is high time we start preaching to our young people in college that this training is without question the best preparation for life. Whether they get into an engineering job is, in reality, of secondary importance. If we can plant that in the minds of our young people, over-production in this country will not be very serious. However, if we do turn out a very large number of students in the next few years unable to find jobs in the field for which they are prepared, we are facing rather serious difficulties as far as the country is concerned.

On the supply side of the picture, therefore, we feel we have a fairly accurate size-up of the problem. The figures I have just given you on the demand side of the picture indicate there are three basic areas that we feel must be carefully surveyed. Just a word on our attempt and procedure.

In the first place, we must know how many people the colleges need to employ as instructors and professors in order to continue their educational processes. We have contacted all of the deans of the engineering colleges in the country. We have received replies from a high enough percentage to believe that we have an accurate idea of the college needs. In 1947–1948 they will be asking for 1,745 people, of which 1,050 are new and 695 experienced; in 1948–1949 for 1,565, 923 new and 642 experienced; in 1949–1950 for 1,360, 630 new and 730 experienced; and in 1950–1951 for 1,160, 510 new and 650 experienced. There is an indication that specialization in schools means a continual downward trend in the demand for additional people in education. We can assume from information received that if we can man the colleges to take care of the present load, future additions to faculty will be unnecessary.

We are having real difficulty in making a good survey of governmental needs. At the present moment we know certain branches of the government have already had very serious budget cuts from the new Congress. This is having a serious effect on our manpower survey. For example, we know the Bureau of Reclamation is laying off thousands of people at the present time. REA is releasing 1,500 people and many other Bureaus are worrying and wondering what their situation will be. It is utterly impossible at this time to get good accurate figures. The best information that Dr. Trytten can bring us from his contacts in Washington is roughly that an additional 3,000 a year will be needed from the colleges by the various governmental bureaus. State organizations are in exactly the same boat and in our survey (on which I will touch in a moment) as to the needs for civil engineers, we do not believe that our figures are accurate. We know that a large percentage of the civil engineers go into federal, state and local governments. Our manpower figures for this group are unobtainable. For these reasons we are using the total figure of 3,000 a year for all forms of government.

On the industrial side of the picture,

last year the report was made from a compilation of information from 125 companies. I have mentioned to some of my friends around the circuit that I would guess that there are 3,600 companies visiting the colleges to recruit engineering people. We have gone to the schools and asked them to give us the names of every industrial organization that has contacted them, whether an engineering concern, a bank, or what not. There are all types requiring engineering people and we had, at the time I left, collected the names of 4,247 organizations involved in this particular problem this last year. We have sent to those organizations a simple questionnaire asking for their manpower requirements, and that information is pouring in at a great rate. We have collected information from 605 organizations, and by interpolation have arrived at the following figures:

Industry should demand from the class of 1947, 23,300 people directly from college. They need an additional 9,900 or a total of 33,200. In 1948 they ask for 22,100 new and 8,600 experienced, or a total of 30,700. In 1949 a total of 28,200; in 1950 a total of 26,900; in 1951 a total of 26,100; and in 1952 a total of 25,800. There is a continually dropping curve throughout this entire period.

Another problem facing the schools is that if an organization employs an experienced man, he will have to be replaced by a younger man from college some place down the line. In other words, that figure given as the total demand of industry will be in a large part the demand from the schools themselves.

Another very interesting figure is the total of the results and I will go over that quickly. In 1947, including the demand of industry and government, the total will be 36,200 with a supply of 23,000 or a shortage of 13,200. In 1948 we show a total demand of 35,545 with a supply of 31,000, which is still a shortage of 4,545 boys. In 1949 there will be a total demand of 32,765 and a supply of 36,000 which we believe will probably be about "even-Steven" or on the line, if you will, and in 1950, when the very large freshman class strikes us, the demand will be 31,230 with a supply of 58,000, which indicates a surplus of 26,770 people. Going on to 1951 we will have a surplus of 22,740, which drops a little from the great peak unless our attrition is very, very high, unless we work harder to eliminate the poor ones.

These boys ought to be warned that it is not necessarily a very serious situation if they do not find jobs in the companies that employ engineers. They should realize there will be an oversupply in 1950, but that an engineering education is basically as good an education for life as any they can take.

Quickly breaking down I will give you the various types of engineers in which I think you would be interested. The aeronautical group is already oversupplied according to the figures. There is an oversupply which will increase for the next four years up to a maximum of 1,650. It is a relatively small group.

There is still a heavy demand for chemical people and this will continue throughout the period coming out with a slight surplus which will mean, if anything, a balance or still a small shortage in 1950.

For civil engineers we do not have figures that are of any value. We do not have a sufficient picture of the

demand side to make the figure accurate. We believe generally that the civil engineer balance will not be reached before 1951. They will still be needed in large numbers with the expectation of many government projects.

The electrical engineers are the serious problem. It is increasingly clear that we are going to have a considerable oversupply in 1949 and an exceedingly high oversupply by 1950. I feel we should watch that very carefully as there are large numbers being attracted to the electrical phase of engineering due to the various contacts the G.I. had in the war with different phases of electrical engineering, such as radar, etc.

For mechanical engineers there is a tremendous demand and it will continue. Our figures show a slight oversupply in 1950, but it is not at all serious and I feel that we can use good mechanical engineers as fast as they can be produced.

Mining and metallurgy show a slight oversupply which we feel is wrong. We think there are many more places for engineers of this kind.

As for other groups, from the best information we can obtain by putting all other kinds of engineering into a lump, as we did in last year's report, we have found there will be a heavy oversupply. It would be wise to encourage some of these boys to switch to mining and metallurgy or mechanical engineering.

Very briefly, gentlemen, that is an interim report by your Manpower Committee. We are going to have to ask for more and more help, and as Dean Harry Curtis at the University of Missouri wrote me, "Your confounded questionnaire came in," and I suppose I will have more statements of that kind pretty soon. This is an important subject and your Committee intends to keep on working with it. We hope that well before enrollment begins we will be able to supply you with accurate substantial figures on which you can base your judgment.

A Proposed Engineering Aptitude Test for High School Students

By K. W. VAUGHN

Director, The Measurement and Guidance Project in Engineering Education

Introduction

The Measurement and Guidance Project in Engineering Education is engaged in systematic development and evaluation of tests and examinations designed to reveal aptitude and achievement in various stages of the engineering curriculum. In this examination structure, provision has been made for the construction and validation of an engineering aptitude test suitable for high school sophomore students. The purpose of this paper is to outline general principles which will guide the development of this test and to describe briefly the major abilities and achievements which appear to be necessary components of engineering aptitude.

I. The Need

An aptitude test suitable for discovering possible engineering talent in the high school may properly be classed as a guidance test. It is generally recognized that a guidance test should be administered at a time in the student's development when he needs to have information concerning his potentialities and the areas in which his energies and intellectual development may properly be directed. Furthermore, such tests should be available at a time when there remains an opportunity for the student to complete the necessary stages of development before specialized college study is undertaken. That is, the student should be provided with dependable measures of his capacity for the further study of scientific subjects as early as possible if he is to prepare himself for the study of engineering. It is not enough to ascertain the student's interest or his achievement in formal courses to serve as a basis for such guidance. Carefully-constructed tests should be used to provide dependable and objective estimates of individual possibilities and potentialities.

It is generally recognized by educators, guidance officers, and psychologists that the high school student's interest and study pattern can be modified by intelligent advice which becomes more effective when supported by objective evidence provided by examination or test scores. Admissions officers and deans of engineering generally prescribe a series of subjects which students are required to have completed before the engineering curriculum can be undertaken. While such prerequisites are generally well publicized from the point of view of the college of engineering, this information sometimes does not get into

* Presented at the 55th Annual Meeting, A.S.E.E., Minneapolis, June 18–21, 1947.

the hands of students soon enough to permit the student to choose a course of study which will lead him into the study of engineering. A systematic guidance program in secondary schools, which provides adequate testing instruments and occupational information, and places this information in the hands of students at appropriate times, can do much to guide prospective science and engineering students into proper advanced courses in the last two years of secondary school study.

From the point of view of the engineering curriculum, the sophomore year in high school is an appropriate point to begin exploring the potentialities of individuals with respect to the possible study of engineering. Generally, the student has completed two years of the basic sciences—general science and biology. In many high schools, students will have completed elementary algebra and plane geometry. This pattern, of course, varies considerably in various parts of the United States and among high schools with divergent philosophies concerning the place of formal mathematics in the secondary school curriculum. In general, however, the student will have pursued the first science courses and the elementary mathematics courses which are fundamental to the subsequent study of engineering. By having taken such subjects, most students will have formed a very definite opinion as to their interest in further study of these fields in high school and will possibly have projected their interests forward into the college.

While the elective system within the last two years of high school is relatively restricted as compared with college curricula, there is in most cases an opportunity for the student to elect further courses in science and mathematics during the last two years of high school. Thus, the end-of-year high school sophomore student who is soon to register for his junior courses should be provided with some basis for evaluating himself in relation to his educational study plan. In this connection, he can be advised of the information provided by aptitude tests, interest tests, and other objective instruments which can assist him and his counselors in making decisions affecting his further study.

It appears, therefore, that there is a need for an engineering aptitude test at the high school sophomore level and that such an instrument will be of considerable value in the guidance of high school students.

II. General Principles of Development

In developing the engineering aptitude test, the Project staff will be guided by several practical and technical principles. Some of these principles are general in character and others serve as standards for evaluating the test materials as they evolve through successive stages of development. Certain of the most important of these principles will be discussed briefly.

1. *The purpose of the engineering aptitude test will be clearly defined.*

The purpose of the proposed engineering aptitude test is to provide measures which are predictive of the student's success in advanced mathematics and science courses in the last two years of high school study. It is assumed, and there is much evidence to support this assumption, that abilities developed in these subjects are most predictive of initial success in the first

stages of the engineering curriculum. This fact has been borne out repeatedly in researches of the effectiveness of the Pre-Engineering Inventory.

Secondly, the performance on the engineering aptitude test must be related to success on the Pre-Engineering Inventory. Specifically, the purpose of the engineering aptitude test is two-fold in character: (1) performance on the test must predict, with good precision, the student's later success in scientific subjects in the high school; and (2) individual performance on the test must also be highly related to performance on certain sections of the Pre-Engineering Inventory.

2. *The engineering aptitude test must be valid for its purposes.*

One essential aspect of test validity is that the results derived from an examination are dependable for the operating purpose of the examination. In general terms, an individual who receives a high score on the engineering aptitude test must systematically achieve a better understanding and competence in subsequent courses in high school mathematics and science than an individual who receives a low score on the test.

If the aptitude test were perfectly valid, it would also be perfectly reliable, that is, the individual who received the highest score on the engineering test in any group of sophomores would consistently be the best student in advanced courses in the fields of mathematics and high school science. Similarly, all other individuals would retain their relative position in achievement as forecasted by the measures of aptitude. This, of course, is too much to expect of any examination. However, a definite effort must be made to increase the precision of the aptitude test so that guidance officers in high schools can predict with good precision the individuals who are likely to experience difficulty in the advanced study of mathematics or science and to identify those individuals who would profit by continued study and possible preparation for engineering study at the college level. Validity, then, will be our essential problem in the development of this examination.

3. *Each sub-test must be as reliable as possible.*

In test development, reliability is a correlate of validity. In the case of aptitude tests, validity may depend very largely upon the factors or components of success which are measured. Reliability deals with how effectively such factors are measured. To illustrate, scholastic ability does not account for nearly all of the failures which occur in the secondary school. It would be possible to enumerate a long list of other considerations which must be taken into account when an individual does not achieve satisfactory marks in science, mathematics, social studies, or other secondary school subjects. However, if we are to ascertain what role scholastic ability does play, it is necessary to measure such abilities as precisely as possible.

To illustrate further, is is certain that the engineering aptitude test must include a section dealing with mathematics. Our first problem is to measure as dependably as possible the student's general ability in this area. We have criteria by means of which it is possible to tell how dependably we are measuring mathematical ability. When we consider validity, however, we are concerned with the problem of

how much mathematical ability contributes to the success of individuals who continue the study of this and related subjects.

4. *The results on the aptitude test must be differential in character.*

Guidance tests where more than one ability is measured should provide for differential scores. Except in unusual instances, it is generally desirable to provide separate scores for each ability or subject area included in a series of test. The engineering aptitude test will provide at least four measures, and possibly five, depending upon the scope of the series. The report to students and counselors will be in the characteristic profile form in which relative performance in each of the abilities can be shown graphically. In addition to scores on the separate tests in the series, a composite score will be provided.

5. *The test will be efficient in scope and in administration time.*

While short tests are most easily administered, it is not always possible to devise a short test which is both reliable and valid. Thus, we shall be first guided by validity; secondly, by reliability; and thirdly, by efficiency of administration time. It is certain that the test will be reduced in length as much as possible in order to encourage its use and without impairing its value from the point of view of guidance.

6. *The tests will be difficult.*

One of the most significant findings of the early experimental work was concerned with the difficulty of available test materials. Tests of ability in mathematics and science which are properly adjusted in difficulty to the abilities of all students enrolled in the high school, or college freshmen generally, are not sufficiently difficult for prospective engineering students. The engineering aptitude test will necessarily be a difficult test. It will distribute effectively the scores of the upper one-half of groups in mathematics and science courses; below-average students will find many questions which cannot be answered or problems which cannot be solved correctly. Only in providing a difficult test at this level will the differentiation necessary for proper guidance be provided. Naturally, the test materials will not be so difficult that capable students will be unduly discouraged.

III. Principles of Construction

It is not necessary to discuss here the specific principles of test construction and development which will be utilized in the writing and refinement of the test questions and the sub-tests in the series. It may be of interest, however, to present here a brief discussion of the major abilities to be sampled by the test. Data which support the plan for constructing the tests are reserved for a succeeding section.

It is expected that three major abilities will be sampled by the aptitude test. A fourth ability remains in question, and probably will be provided in a separate test which will be optional on the part of counselors and teachers. The three abilities which will definitely be sampled by the test are: (1) ability to comprehend and interpret scientific materials, including scientific vocabulary; (2) general mathematical ability; and (3) ability to comprehend mechanical principles. The optional test is spatial visualizing ability. In the Pre-Engineering Inventory, the tests which measure the ability to com-

prehend the meaning of important words in the vocabulary of high school science and mathematics and the ability to comprehend and interpret reading materials in scientific fields have consistently proved that their results provide a good prediction of a student's success in engineering subjects. In general, the materials included in the test which combines vocabulary and reading comprehension of scientific materials will be concerned with general science subjects. Some emphasis will be placed on biology, although biological concepts will not be sampled nearly to the same extent as will the various topics included in general science courses.

The test of general mathematical ability will measure the student's ability to solve problems ranging in difficulty from arithmetic through plane geometry, to interpret graphs and tables, and to apply mathematical thinking to the solution of new problem types which the student has not previously encountered in his formal study, but for which he presumably will have developed the ability to proceed in an orderly manner. This test will measure both achievement and aptitude, and may properly be called a general ability test.

Although of limited use for perdicting general success in the study of engineering, the ability to comprehend and apply physical principles and to solve problems involving direction of motion, and mechanical principles at an elementary level is probably a very necessary aptitude for a study of physics. It is believed also that this test will be an indicator of interest and therefore be of considerable value for the student's readiness for the study of physics or chemistry.

A spatial visualization test may increase the length of the series beyond the point of efficiency. Unquestionably the ability to visualize form and detail from plane figures is an important aptitude for a limited aspect of engineering study. It may be desirable to include this test in the aptitude battery, or it may prove more feasible to provide a separate test of this ability. The decision in this matter cannot, of course, be made immediately.

Experimentation will be conducted with each of the four tests already described.

IV. Pertinent Data

The decisions concerning the content and emphasis of the engineering aptitude test are based largely on experimentation with engineering freshmen. These experiments were conducted in connection with the development and validation of the Pre-Engineering Inventory. It will be of interest to present here data concerning the predictive value of the seven tests included in the Pre-Engineering Inventory.

Lacking uniform criteria among the colleges of engineering participating in the Engineering Project, our initial researches on the predictive value of the Pre-Engineering Inventory must necessarily be based upon the relationship of test scores to grade-point averages as reported by the college of engineering. As is generally recognized, this procedure is not entirely adequate. Grade-point average as a criterion has serious limitations and the resultant correlation of test scores with this criterion does not ordinarily produce correlation coefficients in excess of .60. Multiple correlation procedures in which each of the several tests in a battery is weighted in ac-

cordance with its relative contribution in the matrix are usually necessary before such a predictive value is achieved.

When these factors are taken into account, a battery of tests which produces such a correlation of .50 to .60 is considered adequate for purposes of guidance and, in many cases, selection. Indeed, most colleges and universities utilize test batteries whose validity coefficients (as based on the grade-point criterion) are very much less than .50. When test batteries whose composite scores correlate with grade-point average during the first semester or first year of study of the order of .60 or higher, the battery is usually classed as a superior instrument. Individual tests which correlate with this criterion or course grades in excess of .50 can be considered as most useful for purposes of predicting success in the subject or area.

Let us consider now the correlation of scores on the several tests in the Pre-Engineering Inventory with grade-point average during the first semester of study in ten colleges of engineering. Only summary results are presented for this group of colleges which administered the Pre-Engineering Inventory in the fall of 1944 and, in four cases, in the fall of 1945. The colleges represented in the data presented below are:

- The California Institute of Tech-Technology
- The University of California at Los Angeles
- The Carnegie Institute of Technology
- Georgia Institute of Technology
- Massachusetts Institute of Technology
- The University of Michigan
- Newark College of Engineering
- North Carolina State College of Agriculture and Engineering
- Oklahoma Agricultural and Mechanical College
- The University of Texas

Each of these colleges of engineering administered all seven tests included in the Pre-Engineering Inventory with the exception of one college which did not give *Test VII—Understanding of Modern Society.* The composite score on the battery was an experimental one and based only on *Test II—Technical Verbal Ability, Test III—Comprehension of Scientific Materials,* and *Test IV—General Mathematical Ability.* The following tabulation presents the range of correlation coefficients between test scores and first-semester grade-point average and median correlation coefficients for each test. These follow:

		Range	Median
Test I	General Verbal Ability	.16–.50	.38
Test II	Technical Verbal Ability	.25–.55	.47
Test III	Comprehension of Scientific Materials	.41–.65	.55
Test IV	General Mathematical Ability	.51–.71	.62
Test V	Comprehension of Mechanical Principles	.30–.55	.39
Test VI	Spatial Visualizing Ability	.22–.42	.35
Test VII	Understanding of Modern Society	.25–.53	.41
Composite Score		.44–.68	.62

The variations in correlation coefficients among a group of colleges of engineering are indeed striking. There are many explanations of such variations and no generalization will apply uniformly. Correlation coefficients themselves have limitations for purposes of interpretation and analysis. Sometimes it is necessary to resort to a consideration of the original data and to deduce from distributions of test scores and criteria why certain correlations are low or abnormally high. In many instances, it is not possible to explain such variations.

It does not follow, however, that such variations in correlation coefficients as are reported above negate analysis for purposes of projecting plans for a new series of tests. If we consider the median correlation coefficients for the several tests in the Pre-Engineering Inventory, we can conclude that the general mathematical ability test, the comprehension of scientific materials test, and the scientific vocabulary test are most predictive of grade-point average. This is as we would expect since success in engineering study in its initial stages depends very largely upon the student's mastery of scientific subjects.

While performance on the test of ability to comprehend mechanical principles is not highly related to grade-point average, scores on this test have been observed to correlate with grades in college physics courses to the extent of .51 and engineering drawing to the extent of .56. Although the correlation of general verbal ability with grade-point average is almost exactly that obtained for the ability to comprehend mechanical principles test, the correlation between the general verbal ability test scores and course grades in physics is .32 and in engineering drawing .15. Therefore, the mechanical principles test appears to be very much more valuable for predicting success in physics and engineering drawing than the general verbal ability test.

The spatial visualization test in certain institutions correlates with grades in engineering drawing to the extent of .67. Thus, this test predicts with unusual accuracy the student's achievement in engineering drawing, and while this subject is only one of the several subjects included in the first year of engineering study and is dissimilar in character to much of the work done during that year, it is nevertheless a prerequisite to descriptive geometry and to continued success in the engineering curriculum.

One finding reported in the above data is of particular significance to guidance officers and counselors, although it has less implication for the construction of the aptitude test. This is the fact that the understanding of modern society test is a fair predictor of first-term grade-point average. While there is considerable variation in their social studies courses and content in colleges of engineering, in many colleges considerable emphasis is placed upon this area of instruction. Thus, the guidance officer and counselor, when discusing the results of the aptitude test with prospective engineering students, should also point out that achievement in social studies during the last two years of high school will also be an important asset in the college of engineering. Similar emphasis may be placed upon the field of English, but since both social studies and English are generally required areas in the secondary school, at least through the junior year, the engineering aptitude test will not attempt

to provide achievement or aptitude tests in these areas. It should be re-emphasized, however, that the counselor and the student must recognize that an average or superior achievement in English and social studies will be a decided asset to the prospective engineering student.

V. Summary

The Measurement and Guidance Project in Engineering Education will construct and validate the first form of the Engineering Aptitude Test for High School Students during the next school year. This paper has been concerned with plans for developing the tests to be included in this series.

In summary:

1. It has been pointed out that there is a need for a guidance test at the high school level which will provide dependable scores for purposes of advising students of their potentiality for the further study of high school mathematics and science in preparation for the study of engineering. It is believed that this test should be administered during the sophomore year in high school when opportunity remains for students to elect further courses in high school science and mathematics.

2. General principles of test development were presented. These dealt with the validity of the testing instrument, the reliability of the individual tests in the series, and the difficulty of the materials to be included in the series.

3. The projected series of tests will include tests of three major abilities: (1) ability to comprehend and interpret scientific materials, including scientific vocabulary; (2) general mathematical ability; and (3) ability to comprehend mechanical principles. A test measuring spatial visualizing ability may be included in the series, or this test may be prepared as a separate, optional test.

4. Data concerning the validity of the several tests in the Pre-Engineering Inventory were presented. These data indicate the advisability of proceeding with the measurement of mathematical and scientific ability as the basis for an engineering aptitude test at the high school level.

5. Finally, it must be reemphasized that the results of such a series of tests must be interpreted in light of specific information concerning the prerequisites of engineering curricula and the nature of this field of study. It was pointed out particularly that superior achievement in high school English and social studies will undoubtedly prove a highly desirable asset on the part of the prospective engineering student.

Developing Creative Ability in an Educational System

By K. B McEACHRON, JR.

General Electric Company, Pittsfield, Mass.

I. What Has Been Accomplished

Before discussing specifically the subject assigned to me this afternoon, I should like to review with you the engineering educational system and to recall its objectives and accomplishments in this field. With this as a background we can then better appreciate the problems of developing creative ability and more accurately determine their solutions.

The great and pressing need of industry over many years has been for college trained engineers who could analyze complicated engineering problems by reducing them to their simplest terms and applying fundamentals of engineering to their solution. The colleges early recognized this need of industry and have organized their curricula to meet it. As a result, the engineering curricula contain more theory in mathematics and science and more specific applications of natural laws to material things than any others. Because the graduate in industry has been more concerned with the analyses of machines and processes, the average college student has received much training in analytical methods. This objective approach to engineering and science has so revolutionized our thinking and views of education in general that we have described it as an entirely new method of learning and labelled it "The Scientific Method." The colleges and universities, of this country particularly, have pioneered in the training of young men and women in this new concept and our industrial empire is mute testimony to the success of these efforts.

Recently this Society and engineers generally have recognized that the engineer has a responsibility above and beyond that of producing materials and machines to raise the standard of living. He has also a definite responsibility to see that the products of his efforts are used constructively and for the good of *all*. The results of this new thinking are contained in the reports to the Society by its Committee on Engineering Education After the War and in the definite plan of many schools to include in the engineering curricula subjects with humanistic and social implications in addition to the technical and specific. This second demand of industry and society in relation to the education of engineers has thus also been recognized by educators generally and definite steps have been taken to meet it. In this area, however, the problem is not nearly so concrete nor the answers so obvious as in the area of purely tech-

* Presented at the 55th Annual Meeting, A.S.E.E., Minneapolis, June 18–21, 1947.

nical training. The shaping and molding of the attitude and philosophy of prospective new engineers is a much more difficult job than their technical training. We all recognize, however, what success in this attempt may mean, not only for the engineering profession but for society as a whole.

II. The Problem

The developing of creative ability is neither so specific as the acquiring of technical knowledge nor so nebulous as the creation of attitudes. However, the developing of such ability presents possibly an even greater challenge to engineering education than the developing of attitudes. Creative ability is not only a state of mind but also, in our society and in industry, a process of action. In a world where physical results are the chief measure of accomplishment and even of invention, creative ability is valued only when it results in new methods or new designs. Creative ability, therefore, might be considered to consist of two parts: mental and physical—creative and reduction to practice—and both are essential. An artist becomes great only as he places on canvas the pictures in his imagination; a creative writer is recognized only by his literary accomplishments; and a creative engineer will be acknowledged only as he reduces to practice his ideas.

Developing creative ability from the standpoint of education is, thus, a problem which requires more emphasis on the actual construction of devices than the normal engineering curriculum and a mental training of a character substantially different from that of a normal curriculum. To complicate the problem still further, creative ability can be developed most successfully only by individual attention. As is true in almost any field, the creative mind does not lend itself to systematized training and the developing of such minds can therefore be approached only with a sincere appreciation of this fact and with the attitude that the educational system must be altered wherever necessary to meet the need.

III. Fundamentals of the Problem

The training of people at any level and in any field consists of selection, training, and placement. Although the engineering college is clearly responsible only for training, its success in this area will be obviously effected by the selection of those to be trained, and perhaps to a lesser extent upon the placement of those previously trained. Because there generally is a serious lack in industry of men with creative ability, there are ample placement opportunities during the foreseeable future. Our interest at the present time, therefore, is mainly concerned with selection and training.

A. Selection

The best engineer is one who not only has creative ability but also has a considerable amount of competence in engineering analysis. Those who have some competence in both the creative and analytical fields will for the most part, graduate from high school successfully and qualify for admission to colleges and universities. Careful guidance and counseling of these men in their freshman year should uncover their dual abilities and interests and encourage maximum development in both areas. There are, however, a larger number of men who have a considerable amount of creative ability with very little proficiency in

analysis. Because our educational system from the grammar school through the college is primarily based upon analytical achievement. such men may finish high school with poor records, if they graduate at all. The selection of those with creative ability, therefore, cannot be adequately accomplished only at the high school graduate level. It is a job which must be begun in the first grade of grammar school. Some attempt must be made during this period and the high school experience to encourage those with creative ability to develop their natural talents rather than to stifle them with more and more theoretical and analytical techniques. However, it is clearly impossible for the colleges to reach much below the high school graduate. Primary and secondary schools must accept their responsibilities in this matter and must work with the colleges to insure the continued development of creative people. We cannot, however, understand the whole problem without recognizing that the selection of young people with creative ability is not a question which can be completely answered by selection at the college level.

Mention should certainly be made at this point of the technical high school which gives students greater opportunity to use their imaginations in the design and construction of small devices. Although the curriculum is still predominately specific and analytical in character, most students who have any creative ability will have sufficient opportunity to demonstrate it during their high school experience. Thus, in the better technical high schools, an attempt is being made, while continuing the training in science and mathematics, to encourage the application of creative imagination to problems in the design of small gadgets.

With the exception of the technical high school experience, the college that is attempting to determine which of its freshmen has creative talents has little educational background on which to base its decisions. In fact, it may be obliged to discount much of the scholastic attainments of the average high school graduate if it sincerely desires to select those with such abilities. Usual aptitude and intelligence tests are almost as useless. There is some hope, however, that with the development of subjective tests such as the Rorschach, some definite criteria may be established for the selection of such people. Improved guidance counseling, particularly in the freshman year, can accomplish a great deal in discovering those with creative abilities. One of the most definite indicators available to the colleges of such ability is the nature of the hobbies and outside interests which students have pursued. There are few boys without some interest in mathematics, electricity, or chemistry. There are, however, relatively few who have such a high degree of interest that they will overcome physical difficulties to have their own machine shop or laboratory where they can rebuild automobile engines or make power plants for boats or model aircraft. Even here, however, it is not always possible to draw the same conclusion from the same apparent set of facts. Two boys may build the same piece of equipment but one may build it from a standard purchased plan and kit where the other may develop his own design and obtain his own materials. Economic circumstances may be responsible for this difference but often it can be traced to the difference in interests. Both may

be builders but only one may have a creative imagination.

The selection of men with creative ability is a difficult but rewarding job. It further is absolutely essential if any degree of success in the developing of creative ability is to be obtained. What experience we have had in industry indicates that creative ability cannot be taught but can only be developed.

B. Training

Creative ability can best be developed by an apprentice system where young men can work with designers whose imaginations and abilities have been well demonstrated over many years. This apprenticeship is particularly valuable if there is an opportunity for each "apprentice" to work with a number of different "masters." He may then catch something of the approach and method of each from which he will develop his own individual plan.

In addition to such assignments each student should appreciate and understand the fundamentals of engineering and be able to apply them to actual engineering problems. However, this classroom instruction should be much less intense and with more emphasis upon the simple fundamentals than the average engineering course. The seminar type of instruction rather than lecture and recitation is much more effective here. The purpose of the study of such fundamentals is to insure that proposed changes for new designs are actually workable and practical to manufacture. Class problems should be designed to develop the young engineer's ability to translate his creative ideas into workable designs.

During the period of training, each young engineer should have an opportunity to develop, design, and construct at least one device of his own choice with the guidance and assistance of an outstanding designer. This project may not involve any ideas original to the art but rather a combination of old ideas which is new at least to the student. Such a project is similar in many respects to the senior thesis which many schools have eliminated. Insofar as the development of creative ability is concerned, the project or thesis type of course is the only real opportunity a student has to try out his own ideas.

IV. What Can the College Do Now?

Most of the aspects of the trend to develop creative ability in young engineers seem more adapted to industry than to the colleges. This, I think, is basically true. Industry will always have to recognize that the colleges cannot be expected to develop creative ability in young engineers in a very complete way. There are, however, several specific steps which most colleges can take to insure that, first, those with creative ability are not eliminated from the school entirely or so forced through the normal educational pattern that their college experience is largely valueless, and second, adequate opportunities are given them to demonstrate their intuitive abilities.

Because the problem is one which so vitally concerns industry and which no matter how successfully begun in college must be continued and extended in such industry, it is essential that plans for stimulating creative ability in a college curriculum be made in cooperation with representatives of industry. To be effective, such representatives should be themselves creative designers rather than adminis-

trators. They should, with representatives of the engineering faculty, constitute a board of advisors whose active and continued interest in the program will have more effect upon its success than any other factor. The representatives of industry should also be carefully selected on the basis of their interests in education generally. Although such a board would probably have no official status, it should nevertheless be kept continuously in contact with the curriculum by regular and frequent meetings at the school or at the plants of the industries represented. If such a board is properly selected, it need be given no charter nor any proposed plan. It will quickly and enthusiastically develop its own. There are, however, some general suggestions which it will probably propose.

A. Design Projects

Most courses in design in present curricula consist of analyzing and testing equipment which has already been designed and constructed. Such courses do acquaint young engineers with the type of equipment they may be expected to work with in industry. However with the exception of the most basic machinery, individual designs of equipment differ widely from one manufacturer to another and the young graduate is not expected to be acquainted with such equipment when he is first employed. Furthermore, the college is expected to give the student basic rather than specialized instruction, and specialized design courses will often give the student an erroneous impression of what he may expect in industry.

Other types of design courses in many present day curricula consist of calculations of specific designs patterned after sample calculations. The student merely obtains practice in juggling the figures to obtain a slightly different result from that given in the text with no real conception of the engineering factors involved. The use of such data drawn almost verbatim from a text requires no original thinking. Such calculations would be much more effective as training if no textbook whatever were provided and the student was asked to make certain designs using his own method and obtaining his own experimental factors.

A third type of design is that which industry largely designates as drafting. Certainly the college does not expect to train experts in this field; yet many college courses give so much attention to detail drafting practices that the student comes to feel that design in industry consists principally of drafting work. Every engineer must certainly have a minmium amount of sketching ability and must understand the rules of perspective and projection but such training does not require the use of pen and ink or even a straight edge. With the pressure on the engineering curriculum for the inclusion of non-technical material, we can hardly justify retaining such design or drafting courses at least in their present form.

The training which all three of these types of design courses profess to give the student can be better and more effectively obtained through a single course which will further demand the exercise of some imagination and intuitive ability. Such a course would consist of the design and construction of small devices selected by the student individually after consultation with the class instructor. Too often in the past, thesis projects have been too large and complex and with too much em-

phasis upon original contributions to the art to be of maximum benefit to the student. The educational purpose will be better satisfied and more such projects can be included in a given class if such devices are small and simple rather than large and complex. The emphasis upon the thesis project is in most cases an emphasis upon research. By contrast, such a design course should stimulate the student's imagination and encourage him to make all sorts of "crack pot" devices. At least one college in the Southwest has scheduled this type of design class with the condition that only students who have demonstrated a certain minimum amount of ingenuity and who strongly desire to take the class will be enrolled. If such a design course is to be effective, it must be elective and not required. It is a serious error to force the unimaginative and purely analytical student into such training. It will not benefit the student involved and will seriously interfere with the training of the rest of the group.

The course proposed is not an easy one to plan or control. If it is to be successful it requires a considerable amount of personal and continuing attention from the college administration. Such design classes, however, will stimulate interest in design and development to an unusual degree, will give adequate opportunity for instruction in sketching and perspective drawing, and will acquaint students with industrial equipment of many varieties.

B. Participation of Industrial Designers

Because creative ability must be "caught rather than taught" it is essential that men with this ability be brought into as direct and continuous a contact as possible with practicing industrial designers and inventors. This may be done in at least two different ways. Such men should be invited to visit the school and work with the students in the laboratory and shop, discussing with them individually their projects and problems. Ample opportunity should also be given for these men to speak to the group as a whole describing their particular approach to the problem of creative design and describing in some detail the design process in their respective industries. Students and faculty alike will be inspired by a first-hand account of the design of a new material or device. Most industries will welcome the opportunity to participate in a program of this kind and will make such men easily available to the schools. To make frequent visits of such men to the schools reasonable, local and nearby industries should be considered first as a source of supply.

C. Faculty Preparation

Since most faculty members have had little opportunity to exercise their own imaginations in terms of design, it is essential to provide some method whereby those responsible for the training and guiding of these embryo designers may develop their own creative ability. In some cases, this may mean spending a considerable period in industry in design and development sections where such intuitive abilities are required. In many cases, there will be no men on the staff who have such ability and the college must look to industry to supply them. In the past, such men have naturally gravitated to industry because of the lack of opportunity to exercise their talents in the educational system. If a real attempt is made by the schools to de-

velop those students with some measure of creative ability, creative designers with an interest in education may be expected to consider favorably entering the teaching profession.

A program for developing creative ability in an educational system will be ineffective without adequate supervision and instruction. This part of the problem, therefore, is of primary importance to the success of the whole.

V. Design for the Future

Because of our pre-occupation for the past many years with the education and training of men in theory and analysis, we cannot look for immediate results in the developing of creative ability. As suggested earlier, the primary and secondary schools as well as the colleges have a responsibility to discover and develop such ability which in no part of the education system has, as yet, been adequately recognized. The Society is to be congratulated in this connection for its interest in this field and for its desire to do something about it. We must expect a long and difficult period before any measurable results in terms of adequately trained students can be looked for. The need of industry for men with imagination and ingenuity has been steadily increasing as its needs for analysts and theoretically trained personnel have been more nearly met. We can anticipate that in the future, this need will become more intense; and the developing of creative ability in college students must be begun at once.

The lethargy of other parts of the educational system should not be an excuse for lack of action by the colleges. Within their own sphere, institutions of higher learning can take many steps to further the development of creative ability.

However, in the process of stimulating ingenuity in the educational system, we must not overlook the fact that the ingenious designer is still fundamentally an engineer and must have an understanding of the fundamentals of engineering. Furthermore, he is interested in the same areas of activity as the other members of his class. It is, therefore, a grave mistake to establish a separate curriculum or to segregate those with creative abilities from the rest of the group except as their natural interests and desires dictate. A program to develop creative ability should be a part of the regular engineering curriculum and not apart from it. There is no excuse for establishing a separate curriculum and the entire program will only be harmed thereby. Because true creative ability is not confined to a specific area of engineering it cuts across all phases of the engineering field and unifies and integrates rather than segregates or partitions engineering training. A program for the developing of creative ability in an educational system must therefore be one common to all engineering fields if it is to be most effective.

In the last analysis, a creative designer is one who brings to bear all of his knowledge and all of his imagination to the solution of a complete problem no matter how many separate fields may be involved. The broader the training in engineering, the more opportunity there exists for the development of creative ability and the stimulation of ingenuity.

The Philosophy and Curricular Content of a Graduate Program in Electrical Engineering*

By H. L. HAZEN

Professor and Head, Department of Electrical Engineering, Massachusetts Institute of Technology

In asking for a paper for this joint session of the Graduate Division and the Electrical Engineering Division of this society, your chairman mentioned the fact that a number of colleges throughout the country are expanding their graduate programs and that the point of view and experiences of a department that has carried on graduate work for many years might be of interest. In accepting this invitation, I am under no delusions that we have all the answers or that the answers we think we have to the problems of graduate study are the only ones, the best ones, or even right ones. Education at the advanced levels remains much more of an art than a science, guided by men and ideals. Because men and ideals are the primary and determining elements in the value and effectiveness of a graduate program, I propose to devote the major part of this paper to these, leaving rather minor emphasis on the subject of programs of study.

Please do not misunderstand me in this statement. I do not think that study programs are of no importance at the graduate level. Rather, I believe that men and ideals are far more important; and that if these are of suitable character and level, the questions of study program will in the normal course of events be given their due emphasis and study, with a result that one can justifiably expect to be soundly conceived and adequately planned.

In accord with this point of view, I propose to approach the subject of this paper as follows. First, we shall consider the objectives of graduate study in some detail because these are the necessary foundation on which to base any discussion of methods, study programs, staff and facilities associated with a graduate school. These objectives are illustrated by comparing characteristics of work at the undergraduate, Master's, and Doctor's levels, and by examining how typical graduate study fields contribute to these objectives. Second, graduate work imposes certain requirements as to staff, facilities, and adminstrative policy that must be recognized and faced if a school is to undertake a serious graduate program. These requirements are discussed. Third, there appear to be certain broad characteristics in terms of which one can describe a graduate study program. These I should like to present for your consideration.

* Presented at the 55th Annual Meeting, A.S.E.E., Minneapolis, June 18–21, 1947.

As the point of departure, we ask the question, "What is the purpose of graduate study?" The ready answer to this question is "specialization." While in a certain broad sense this is true, I believe that the educator who goes no deeper misses the true spirit and purpose of graduate study. In support of the "specialization" objective, an observer of my own department can very easily cite, for example, special graduate curricula formulated, with many a discussion, to meet certain supposed clearly specified and defined objectives for officers of the Armed Services. There is some truth to the idea that gradute work achieves specialization. Nevertheless, I hold strongly that this is a rather superficial and obvious aspect of what a graduate teacher seeks to accomplish.

The real objective is to lead the student to a more profound and thorough understanding of elementary scientific principles and to assist him in developing that mastery both of principle and of method of attack which will enable him to lead out in new fields with greater competence and assurance.

Here I should like to refute once and for all the widely held notion that graduate work in electrical engineering is conceived as primarily preparation for research. Rather, graduate work is conceived as helping a man better to tackle any engineering job requiring a fresh and fundamental approach, as contrasted with competently applied well-known methods.

Interestingly enough, the apparently "specialized" graduate subjects bring to the student the realization that his supposed understanding of elementary principles is restricted in scope and hazy in concept. This realization sends him back to restudy—with greater purpose and more critical perception—the first principles, of which he had previously assumed he was the master. Masterful grasp of first principles is cardinal. How often has each of us observed that the leader in science or its applications in engineering is characterized primarily by his ability to strip the complications from an apparently complicated situation or problem and to bring clearly into focus the simple elements that are its core. Such ability is more valuable than any amount of merely specialized knowledge.

"The "advanced" or "specialized" graduate subjects do, of course, provide a certain readiness of technique. These may be immediately useful and sometimes attractive to an employer, but the enduring result of graduate study is the deepening of understanding and the developing of that competence and assurance that enables a student to recognize and apply basic principles in new and different situations.

One may enlarge upon this point by a comparison of the undergraduate, the Master's, and the Doctor's level of work and outlook in engineering. Most of the undergraduate student's time and effort is devoted in the professional area to learning and making simple applications of elementary principles of mathematics and physics. The teacher often guides the student, sometimes in great detail. The problems which he is given to solve as a medium of learning principles do not vary too greatly from those discussed in the text or by the teacher. The good undergraduate teacher, of course, continually strives to make the student take steps by himself, but the less inspired teacher is prone to tell rather than to stimulate. Occasionally,

through the medium of comprehensive examinations or an undergraduate thesis, the undergraduate student is presented with problems of broader scope and further removed from his previous experience than the usual home problems. By and large, however, the undergraduate student sticks reasonably close to the beaten track along which he has been led by his instructor.

The beginning of graduate work can well mark a certain discontinuity in the student's experience in regard to the amount of thinking he is expected to do for himself and the general professional level of his accomplishment. The problems that he is given should be stated in more general terms and as a consequence require more thinking and judgment for the formulation of their quantitative aspects than the problems to which he has been accustomed as an undergraduate. He should be expected to have to go to the literature for assistance and even for basic text material more frequently than he ever did as an undergraduate. In the Master's thesis, if he is required to do one, the problem should be of substantially greater scope and difficulty than can be required of an undergraduate. In all these aspects the emphasis is thrown much more strongly in the graduate year on individual initiative and thinking.

At the doctorate level this stress on individual drive, initiative, and self-reliance is again increased. The doctorate student is almost by definition one who has a large measure of ability to formulate and pursue, at an independent and scholarly level, work of an advanced character. This does not mean that he works in isolation without the aid of his professors and associates. Rather, he consults with them on a personal and professional basis as one who, having already studied a problem and clearly thought out all of its straight-forward aspects, has singled out and defined the more advanced phases requiring creative thought and seeks the benefit of mutual discussion. Here the teacher's function is that of a counsellor as to broad objectives and general lines of attack, who offers the benefit of perspective stemming from his experience. Detailed guidance would rightly be resented by the student.

Thus the later stages of the doctorate program, though necessarily associated with a specialized subject or area, are significant not because of this specialization but rather because of the relatively mature development of the student's skill in applying the scientific method, his profound understanding of fundamental principles, and his ability to carry through independent, creative, and productive work on his own initiative. The soundness of this concept was demonstrated brilliantly in unnumbered cases during the recent war, in which civilian scientists trained in this philosophy made outstanding contributions in record time in fields quite unrelated to any previous area of "specialization." Their previous "specialization" had served as the *medium* of training, not as its *end*. The concept of the doctorate as a final stage in the process of learning "more and more about less and less until one knows everything about nothing" is unsound and productive of persons of very limited usefulness. This does not mean that profound knowledge and competence in a particular area are not worth while. In fact, the great advances in science are made by people in precisely this position. However (and this seems to me very important),

the capacity for independent and resourceful creative work stemming from a profound grasp of fundamental principles is the primary characteristic of the people who do this work; the specialized knowledge is basically incidental. Such persons rapidly develop specialized knowledge in any field in which they need it.

This specialization-versus-deepening aspect of graduate work is well illustrated by the experiences of students working in some of the fields which are currently popular in electrical engineering graduate study at the Massachusetts Institute of Technology.

Servomechanisms and automatic control constitute a very popular area. This field sounds very specialized—so specialized indeed that the casual observer could legitimately question whether, in teaching it, one has not forsaken fundamentals for *intensive* specialization. Almost paradoxically we find in practice that it becomes an extraordinarily effective medium for deepening and broadening the grasp of fundamental principles, an experience that I believe many of you have shared. Thus one immediately comes face to face with the dynamics of lumped-parameter systems including active elements. Questions of dynamic stability and of detailed behavior under transient as well as steady-state conditions must be answered quantitatively. One finds that the steady-state response to periodic driving forces over a broad frequency range is equally important.

This type of analysis, of course, requires the accurate description of the behavior of the significant elements in terms of differential equations, one of the most difficult and simultaneously most important components of the engineer's discipline. In a servo system one encounters separately or in combination such apparently diverse devices as: electric circuits including electronic devices; hydraulic amplifiers, pumps, motors, and transmission systems; pneumatic systems; and electromechanical devices, including motors, generators, torque motors, selsyns, multi-winding amplifier generators; to say nothing of the chemical, thermal, aerodynamic, mechanical, or other systems which are integral components of closed-cycle systems for the control of such quantities. The servo man must be able to deal quantitatively and analytically with the dynamics of such varied components and of complete systems involving them. At the design level he must understand basic possibilities and limitations with a perception that permits radical departures from previous practice. Thus the servo field is one that compels integration of mechanics, hydraulics, and electric circuits in a way that is a joy to the educator.

Another integration growing out of automatic control is that between the closed-cycle control system and what the electric network people have long called the feedback amplifier. In fact, most of the basic ideas of feedback-amplifier theory carry over to the closed-cycle control theory. Thus the student of servomechanisms and automatic control is required to consolidate his elementary theory of lumped parameter dynamic systems so thoroughly that he recognizes its earmarks wherever he may encounter them.

Another area that has achieved very wide popularity as a result of the war is that of microwaves. No other subject has been nearly so effective in sending the electrical engineering student back to Maxwell to learn the basic physics of electrical engineering,

namely, electromagnetic field theory. The radar and other pulse system applications, most of which are at microwave frequencies, have also enforced the need for a clear understanding of simple resistance, inductance and capacity circuits and electron tubes under transient as well as steady state conditions.

As another example of the "specialization" route to fundamentals, the field of electric insulation—so long forced to progress along empirical lines—is now beginning to draw direct and fruitful support from physics and chemistry at a level that suggests, for the not too distant future, synthesis of materials designed on the basis of atomic, molecular, and crystal properties to meet specific requirements. This applies not only to insulators but to semiconductors, nonlinear circuit elements, certain electromechanical elements, and photo-sensitive devices, to mention a few.

These examples in the field of servos, microwaves, and insulation are illustrative of the way in which relatively borderline fields which are good subjects for graduate work throw the student back to a deeper and more thorough understanding of the underlying science than he has had to achieve previously. In many cases the graduate student sees that with the help of more mathematics and physics he will get a deeper understanding of his engineering principles. Thus the whole spirit and trend in graduate work, when it is challenging and stimulating, is to develop a greater appreciation for and competence in the underlying science, and at the same time to provide a certain amount of "specialization."

Of course there are those students of restricted horizon and limited capacity who persist in graduate work and who see the specialization aspect but never quite grasp the deepening influences. Such become the graduate counterpart of the undergraduate who, having taken one professional subject in machine design, concludes therefrom that machine design is all he ever hopes to do throughout his life. They are members of the graduate-school community in name but not in spirit.

Before leaving this subject of the objectives of graduate study, I should like to touch upon an aspect that is receiving increasing attention at the graduate level parallel to the major attention at the undergraduate level. This is general education, including the human-social stem. This we all know is a large subject, too large to more than touch upon here. Nevertheless we should all be acutely conscious of what can be one of the hazards of graduate work, namely, the too exclusive emphasis on the quantitative and rigorous aspects of science and engineering. Such emphasis—to the exclusion of broad outlook and of humanizing influences—can reach the point where the student is abashed and clumsy, if not entirely uninterested, in those larger, complex, and inexactly understood problems of engineering and of human affairs in which careful weighing of conflicting evidence and human values rather than mathematical methods are the basic elements. Leadership cannot ignore, in fact must give primary attention to, such problems. Leaders are scarce in all fields of activity, including engineering. I think we should make a serious effort, at the graduate as well as at the undergraduate level, to enlighten the student of restricted outlook who would ignore any problem that cannot be solved in terms of equations or numbers. As a matter of fact,

even in engineering and science close logical reasoning and mathematical analysis are prehaps more often used as a means of exploring, bounding, or verifying some imaginative person's bright idea for solving a tough problem, or of explaining an unexpected experimental result, than as the means of discovering new ideas. That is, imagination usually runs ahead of and leads the way for the more systematic and orderly process of mathematical thinking. Some of us educators would feel happier if more of our Sc.D's were potentially fitted to step into their bosses' places, where broad thinking is required.

Surely, then, we should in graduate as well as in other levels of engineering education avoid that one-track emphasis on the mathematical reasoning that leaves the student unmindful of or unsympathetic toward the more imaginative aspects of his profession, and toward the even more important qualities of personal leadership. Leadership involves broad interest, sound judgment, and clear perspective, as well as energy and productiveness. Certainly in graduate work we should encourage and develop these qualities of leadership as well as professional competence in the restricted sense. How to do this is another and far more difficult subject to which all of us need to give thought. The influence of strong able men as graduate teachers is one of the more obvious ways. We cannot solve this age-old problem here, but do reiterate its dominant importance.

Having thus far considered at some length the objectives of graduate study, I turn next to the second main part of this paper, namely, the prerequisites to a graduate-level educational program. In this I wish to emphasize again that graduate work is not just another year in the undergraduate manner. A school may do a good undergraduate job and still lack that which is the essence of the graduate spirit. One cannot have a graduate school by merely willing that one shall exist or by applying a name. Certain conditions are, I believe, essential to achieving a graduate-level program which I shall try to describe in the following paragraphs. These requisites are:

1. Suitable staff
2. Qualified students
3. Administrative support

The first prerequisite, *suitable staff*, is undoubtedly the most important single element because without it one can do nothing, whereas with it one is likely to be able to find the other requisites The outstanding qualification for a staff member for graduate teaching is that he shall be creative-minded. He must be interested in new ideas, have a large amount of intellectual curiosity, and be personally active in or associated with creative professional work of high quality. Only from such a man can the graduate student catch the pioneering spirit. Only occasionally does one find a man who maintains the level of curiosity, scholarly interest and mastery, and intellectual alertness to do well in graduate work who is not personally active in professional or scientific work. Such a man can be a good supporting member of the team, but the essential spirit comes from those who are themselves creative workers.

In addition to being a creative-minded person of real productivity, the graduate teacher—in common with all teachers—should enjoy associating with and developing young people. He

should experience that satisfaction in teaching that any devoted teacher feels to such an extent that he is not happy without a class or some active association with students. Such a teacher incidentally brings vigor and freshness to his undergraduate students, an important influence that a graduate school exerts on the undergraduate school.

There are undergraduate teachers, concerned primarily with people and with teaching for its own sake, who apparently have exerted great influence over their students, but who at the professional level merely keep reasonably abreast of what is going on. They derive their satisfaction from watching young people rise to the thrill of seeing for the first time and understanding ideas which, though old, are new to them. Such a teacher often has a flair for showmanship. He enjoys watching the pattern of student interest develop each year as he tries new tricks and varies his teaching approach and technique from year to year with the idea of seeing what makes the students respond best. Such a teacher is often revered for his personal wisdom and richness and is undoubtedly a great influence in the lives of the undergraduates whom he teaches. Such a man, however, lacks the essence of the graduate teacher, who needs above all to have that spark of imagination, curiosity, and restlessness of mind that keeps him continuously exploring into new territory. One cannot have a graduate teacher, merely by assigning supposed graduate work to one who by aptitude and nature is an elementary undergraduate teacher. Successful graduate work requires that the students experience the personal influence of one who is dealing intimately with the frontier of knowledge in some part of the field.

The second requisite for a graduate program is a suitably qualified group of students. Graduate work is more exacting, both in pace and in depth, than undergraduate; hence only those students whose general intelligence, background and specific preparation are high should be accepted in a graduate school. Such will probably not be found below the top third of a strong undergraduate group. These qualifications are necessary in order that the graduate pace and standard may be maintained. The real graduate spirit, however, comes from those who have something more—those who have imagination and rise with enthusiasm to new and challenging problems and ideas These must have the intellectual character to think independently for themselves. They are willing to challenge the teacher when he appears to be on unsound ground, a challenge incidentally which the real graduate teacher welcomes as evidence that his students are learning to think for themselves. As these students begin to have ideas of their own, their teacher enters his period of reward—that of seeing them gradually develop competence and then confidence to tackle and solve serious and difficult problems requiring new thinking. It is for this kind of student that the graduate school primarily exists. The intelligent but unimaginative person may benefit, but he is essentially an "also-ran" in the graduate school. This second requisite is, then, a student body whose minimum of intellectual qualifications is high but which includes a substantial fraction of those having the mettle and spirit of creativeness.

The third of the three requisites for graduate work, ***administrative support,*** is almost equally as important as the

other two. Administrative support expresses itself in a variety of ways. First, and foremost, it recognizes the creative type of staff required for graduate work and provides the environment that is requisite to securing and sustaining the creative activity of such a staff.

Most important among these en-environmental factors are suitable teaching loads and the opportunity for individual professional work either within the institution or in consulting for industry or government. Graduate teaching requires much more preparation than undergraduate teaching. In this statement I am assuming that even the undergraduate teacher of competence has few pages in his working notes that are more than a few years old. The graduate course that is given twice without change is becoming stereotyped, while a third repetition means that decadence has set in. It takes time and study in generous measure to conduct a graduate course worthy of the name. If the administration persists in including graduate teaching as a part of a heavy teaching schedule, the result is simply stated: The graduate course ceases to be a graduate course.

Comparable in importance with suitable teaching loads as an environmental factor is the opportunity for individual professional work. We are here talking not about the pot-boiling work of routine character but rather about the research or professional consultation that requires and challenges the best efforts.

Research programs within the institution that are well integrated with graduate work can be a very valuable influence and opportunity. Administrative support of such programs thus becomes a great aid to graduate work, both by attracting and encouraging suitable staff and by providing opportunity for staff and graduate-student participation in live and going projects. Such research must be worthy of the name, that is, must involve real and new problems in contrast to glorified testing programs that occasionally are dignified by the term research.

Consulting can furnish equally valuable intellectual nourishment for the staff and live subject matter for students, though it usually lacks the opportunity for direct student participation.

We all know that "light" teaching loads and opportunities for outside professional work or research can be and occasionally are abused. This has no pertinence to their essentiality for the graduate teacher. It merely means that character, conscience, and a sense of fitness are as important in the graduate teacher as in any other person to whom is entrusted a large measure of freedom and responsibilty.

Another way in which administrative support is required, though I suspect this is far less of a practical problem than those factors we have been discussing, is student selection. Any faculty group that is charged with the responsibility for administering a graduate program must have substantial autonomy in selecting the students it will admit to graduate work and in setting standards for degree recommendations. The problem of administrative support here is probably less difficult at the graduate than at the undergraduate level but it is nevertheless important.

Finally, administrative support is essential in the matter of physical plant and facilities, particularly laboratories and the library. The graduate student who is to do experimental investigative

work must have space, he must have equipment, and he must have access to shop facilities. The equipment need not be elaborate, though the lack of some types of expensive equipment may automatically bar certain lines of investigation. Access to shop facilities is probably more important than extensive equipment, since the good experimenter can almost be defined as the one who, given access to the storeroom and a reasonable stock of materials, can devise much of his own equipment. Of course if one has, through institutional, industrial, or governmental funds, the opportunity to have well-developed and instrumented laboratories, the student is spared some of this effort together with some of the valuable education that goes with it.

Among physical facilities an adequate library must be recognized as one of the most vital to graduate work. This library must be easily accessible. Preferably it occupies space contiguous to the laboratories, classrooms, and offices of the staff. A working library for a department giving graduate work at the Master's level should include all of the standard texts and references in the field as well as the principal works in adjacent fields, such as mathematics and physics. In periodicals, a good coverage of domestic journals should be included plus a few of the more important foreign periodicals. For doctorate work none of the reasonably useful domestic or well-known foreign periodicals can be omitted. Also, the coverage in the underlying sciences should include those items to which the inquiring graduate student will want to refer.

In the library, as elsewhere, staff quality is cardinal. A library without an able and enthusiastic librarian is like a laboratory without a good instructor. In either case the physical facility alone has little influence on student thought and education. With able leadership each becomes an inspiring and influential teaching medium, the library being quite commensurate with the laboratory in importance.

In the foregoing discussion of requisites for graduate work, the first—and the one to be most emphasized—is suitable staff. Certain qualities were stressed as of prime importance. How can one determine these qualities? What tests can one apply to a prospective graduate teacher to ascertain whether he has these qualities? There are three tests that are obviously significant. They are: first, the candidate's standing in the profession; second, his interest in education; and third, his personal qualities.

What are the evidences of standing in the profession? One evidence, which I wish to qualify carefully because it is so easily misunderstood and abused, is professional publication. The abuse can occur when publication is made a requirement for, rather than an evidence of, professional standing. The natural response to the requirement of publication as a qualification is that an ambitious person will publish, and publish voluminously, whether he has anything worth publishing or not. We are probably all familiar with this sort of perennial author. On the other and positive side, however, it is clear that professional publications that are recognized as worthwhile contributions by workers in the field are meaningful evidence of professional competence and activity. That is, to regard publication as an absolute requisite is erroneous and dangerous; to regard good publication as tangible evidence of ability is sound. In the absence of good publication,

however, one must insist upon alternative evidences of professional competence and vigor. Another criterion of professional standing is the record of a person's activity in industry, in consulting, or in other forms of engineering practice. Such a record should show rather important responsibility ably and imaginatively discharged. Mere competent carrying-out of recognized engineering procedures is not sufficient. There should be clear-cut evidence of personal contributions of such sort that publication, if appropriate, would be clearly merited.

The person who is known solely as a good teacher, though he may do good and valuable work, does not bring to a graduate school one of its absolutely essential components, namely, personal participation in a creative engineering activity. This staff qualification of personal participation and creative engineering activity is stressed very heavily, because only when this type of thinking is present are the conditions met that make graduate work more than a prolongation of undergraduate learning.

What about the Doctor's degree? The answer is that a good man often has one. Also the holder of the doctorate is often a good man. To go further than this is to invite confusion between the clothes and the man. All too often the degree is regarded as the magic touchstone that eliminates the need for a searching and critical appraisal.

The second criterion for a successful graduate teacher is that common to all teaching, namely, a devotion to teaching activity. It is the joy in seeing young people grow and in assiting them to grow. Neither creative ability nor devotion to teaching alone can provide the essential graduate spirit. Both qualifications are essential. The degree to which a candidate for graduate teaching meets the second requirement is usually readily determined by the candidate's own expressed interests. Very few persons will say they like to teach if they do not, in fact, enjoy it.

The third criterion, personal qualifications, is at once difficult to formulate and important to apply. The student emulates those whom he respects and ignores those whom he does not respect. Those whom he emulates must be worthy of emulation in character and in person. They set the tone of the school. Those whom he does not respect contribute little to the student and are a dead weight on the standing of the school. By "respect," I of course do not mean the outward manners of deference that students naturally accord the position rather than the man. I do mean the appraisal that the students reveal among themselves in their private and brutally frank dormitory sessions. I have much confidence that able graduate students distinguish cannily between the mere "good fellow" and the man of intellectual substance, character, and power.

Having considered the "philosophy" part of the paper in terms of the objectives of graduate study and the requisites to their achievement, we turn briefly to that part pertaining to curricular content. Space does not permit much more than an enumeration of the important characteristics of a graduate program in electrical engineering, this subject being quite sufficient for a paper of its own. However, mention of the highlights will perhaps give an indication of how the foregoing philosophy is embodied in the program of a graduate student

at my institution. These characteristics are the following:

1. *Individual Treatment of Students*

Because of the widely varied backgrounds, preparation, experience, and interests of individual graduate students, an individual program devised after a deliberate and thorough study of his needs jointly by him and a wise faculty advisor is about the only sound solution of the graduate curriculum question.

2. *Individual Unified Program for Each Student*

Good integration of individual courses toward a central interest is required to attain the objective of depth in graduate study. The scope permitted by this objective is normally broader for doctorate than for Master's work.

3. *Relatively Few Simultaneous Responsibilities*

Serious graduate study is incompatible with more than a few simultaneous responsibilities. A maximum of four or five courses, and these not unrelated, are enough at the start, grading to one or two major activities near the end of a doctorate program.

4. *Reinforcement of Gaps in Preparation*

Insufficient preparation for graduate subjects should be frankly recognized as such and corrected by needed preliminary undergraduate work, rather than have the student attempt to do advanced work without adequate grounding, a procedure which usually results in a casualty either to the student or to the class.

5. *Further Work in Mathematics and Physics*

Many students at the graduate level sense the importance of further scientific grounding, an attitude to be fostered and encouraged.

6. *Advanced Professional Subjects or Courses*

These are what the average graduate student expects to take and automatically includes in his program.

7. *Interdepartmental Relations and Interactions*

Departmental lines should be considered purely administrative conveniences without intrinsic significance at the professional level, which students and staff should ignore in the pursuit of their scientific endeavor.

8. *Further Work in Expression*

We believe that continued emphasis on writing and speaking is justified at the graduate level, to the extent of requiring that every graduate student prepare and deliver a substantial professional paper of broad and critical character, the preparation proceeding through several drafts if necessary to attain a high standard.

9. *General Education*

The period of graduate study is not too late to strengthen and broaden interests and understanding outside of the strictly professional field; in fact, once aroused, the motivation in the graduate student is likely to be strong. We are actively experimenting along these lines.

10. *Modern Language*

For the Master's degree we require one, and for the Doctor's degree two, modern foreign languages of profes-

sional importance at the technical reading level. Recent experience shows that this skill can be attained in one term without prior preparation

11. *Research*

We rate very highly the educational value of the skillfully supervised graduate thesis research, considering it the most important single component of the program.

Within the foregoing general specifications a mature advisor designs jointly with the student an initial program that is altered term by term as may prove desirable in response to changing student interest, to particular strengths or weaknesses that develop, or to other changing circumstances. This process we believe is far sounder than a set curriculum at the graduate level and is our answer to the graduate curriculum problem.

Summarizing this paper, I would again emphasize that the objectives of graduate work are to prepare students more fully for undertaking responsibilities departing from the conventional or routine areas of engineering. One thus prepares them by bringing them face to face with the need for a more profound study and understanding of scientific principles and with the necessity of thinking independently in terms of these principles on new problems. This, rather than so-called specialization, is the fundamental purpose of graduate study. In line with this objective, there have been presented certain conditions that may be regarded as essential to graduate education worthy of the name. These are: first and foremost, suitable staff with particular emphasis on creativeness; second, students having the attitude and qualities of mind that can benefit from graduate study; and third, adequate administrative support in matters requisite to graduate education. Certain criteria were stated by which one can test the qualifications of staff to train graduate students. The subject of graduate curricula was approached by giving a number of characteristics which the writer and his associates regard as important in designing graduate programs of study, among which the design of each student's program to fit his specific background, needs, and interests, ranks high.

In conclusion, we should carry on and develop our graduate programs not with the thought of producing cloistered specialists but with the ideal of implementing potential leaders in science and in technology and in the impact of these on the affairs of men. This we can do by helping these students to a deepened grasp on the power of the scientific method. We can develop in them the confidence that this method, when skillfully applied and when combined with a generous measure of human insight and wisdom, can contribute greatly to human welfare.

Functional Laboratory Courses*

By NEIL P. BAILEY and JAMES J. DEVINE
Rensselaer Polytechnic Institute

Introduction

Mechanical engineering education, concerned as it is with *developing power* and *making things*, naturally involves theoretical and experimental courses in each of these fields. The basic problems involved in the development of laboratories and laboratory courses in power subjects are duplicated in the manufacturing processes of metal cutting, forming and casting and in the design functions of stresses, vibration and control experiments.

In all cases it is fairly easy to state general aims and objectives, but quite another thing to develop the actual experiments, laboratory facilities, teaching staff and student attitude to really accomplish them. Since poor results are usually the result of ineffective execution and not of faulty intentions, this discussion will be concerned with some specific and practical problems of laboratory development.

Functional Laboratories

In far too many cases of laboratory course content is determined largely by the experiments that can be readily performed on existing or slightly altered permanent equipment. In entirely too few instances does it prove possible to design an experimental program to fit a given subject matter and then to build a laboratory to perform those functions. Mechanical engineering laboratories are too often in a position comparable to that of a factory with a fixed plant equipment and arrangement that is faced with constantly changing products and processes.

That nebulous group of ideas so blithely referred to as fundamentals is constantly evolving and because new and revised text books go to all schools, class room courses can be kept up to date without too much effort. Laboratories, on the other hand, have a disconcerting habit of not evolving and of lagging not just years but student generations behind in the functions they should perform. When laboratory revisions do occur they are usually widely spaced and painful upheavals that are, on the average, at least ten years overdue.

There must be some rather definite reasons why such a situation should constantly plague mechanical engineering educators and if there are reasons by the same token, there should exist at least partial cures.

Lessons from the Past

The experience of planning and reorganizing the laboratories of four departments of mechanical engineering and of working in a large industrial laboratory during the past seventeen

* Presented at the 55th Annual Meeting, A.S.E.E., Mechanical Engineering, Minneapolis, June 18–21, 1947.

years has resulted in the conviction that laboratory planning of the past has had some inherent weaknesses. It should be useful to list and study the more glaringly apparent of these faults.

(1) Individual pieces of equipment have been excessively large and space consuming, much too expensive and entirely too inflexible. There are certain possible explanations for this.

(*a*) Commercial equipment was generally used instead of developing apparatus especially designed for educational needs.

(*b*) There has been a distinct tendency to look upon laboratory courses as training in test procedures and not as an approach to education from the point of view of scientific experimentation.

(2) Use factors of equipment and laboratory space have been entirely too low. In general this is the result of two things.

(*a*) Again, the equipment has been excessively large, single-purpose apparatus originally designed for industrial and not for educational service.

(*b*) Valuable laboratory space has been occupied year after year by obsolete and unused equipment. In far too many laboratories it is possible to throw away a third of the apparatus without touching anything that has had appreciable use in five years.

(3) In medium and large sized schools particularly, there has been an ever widening gap between laboratory and class room teaching and teachers. This has produced two undesirable results.

(*a*) It has had the effect of concealing from students the complete interdependance between theory and experiment.

(*b*) It has increased the temptation to permit laboratories to become obsolete by making laboratory courses things that can remain unchanged even when the theory courses do progress.

Subject Matter Laboratories

Successive attempts have evolved a scheme which can be called a subject matter laboratory using small, flexibly arranged equipment that gives promise of avoiding many of the troubles previously listed. The general idea may be illustrated by discussing a laboratory devoted to the general subject of heat transfer.

To begin with, if it is one large laboratory space and not a group of small special purpose rooms, the space use factors can be much higher and the temptation to let fixed installations become obsolete is definitely reduced. Also, if heat transfer experiments at all educational levels including graduate work are performed in the same space with flexibly arranged equipment, the use factor of apparatus and instruments can be easily increased.

The disadvantages of having several student groups in one area is more than offset by the improvement in student morale and interest. Juniors doing a rather simple experiment may be working in the laboratory simultaneously with seniors or graduate students doing advanced work and this makes an almost miraculous change in student attitude and interest. It even brings about the very desirable situation of advanced students voluntarily aiding with the instruction of beginners.

The center of the air work in such a heat transfer laboratory could well be a double compartmented plenum chamber designed to meter almost any quantity of air depending upon the

number of nozzles opened up between the two compartments. As many as three independent fan or blower set-ups can be ready for operation on the inlet side and an equal number of tests requiring air can be in operation on the discharge side. Internal sealing doors can make it possible to close off all installations except the one in use and a complete change over to another test may be made in a few minutes. A junior test could be operating one period, a senior set-up the next, and at the same time a graduate research project could be in place.

Such equipment as heat exchangers, spray chambers, burners for hot gases, etc., would be portable units of the same capacity that could be put in place on the discharge side of the plenum chamber or arranged in any combination. By avoiding the use of fixed arrangements, permanently connected together, the temptation to permit laboratory equipment to become frozen and obsolete is greatly reduced. New arrangements to fit changing needs can be readily and cheaply made and a minimum amount of single purpose industrial type equipment would be used. There would be no real need for any unit to involve over ten horse power, so the total investment could be kept low.

The first step in the development of such laboratories is to hire about three good machinists. After going through each course to determine the points that need an experimental approach, the next step is to assign the jobs of evolving the necessary experiments and apparatus to the more ingenious and imaginative members of the staff. The surprise that always comes with such a development is the small portion of the resulting laboratory that uses standard commercial equipment. This is just as it should be, for the real purpose of experimental education is to teach the men who are to develop the next generation of equipment and not just to train them to test a past generation of apparatus.

Laboratories in General

This discussion could do no better than to terminate with a plea that real experimental education receive more emphasis in mechanical engineering. A changing point of view is clearly reflected by the disappearance of book titles such as "Experimental Engineering" and the appearance of books called "Plant Testing" and "Laboratory Manuals." Too often all instruction is done in theory classes and laboratory work is routine and laboratories are uninteresting.

A properly planned laboratory is a powerful teaching tool. Such things as partial pressures, characteristics of vapors, differences between internal energy and enthalpy, momentum concept any many other basic points can be best taught in the laboratory. Far too often the professor who lectures in a classroom is prone to think of the laboratory only as a place where younger teachers must toil out an apprenticeship biding the time when they will be admitted into the fraternity of theory teachers.

Engineering is an experimental science, not an accumulation of immutable laws, and generation after generation of textbook scientists could dry up mechanical engineering progress. Laboratory courses that awaken keen interest in both students and teaching staff are too few but not too difficult to realize. It is time to cease lip service to laboratories and make them into the vital educational influences that they are pretended to be.

The Place of Engineering Experiment Stations in Agricultural Engineering*

By ROY M. GREEN

Dean of Engineering, University of Nebraska

This cannot presume to be a discussion by an expert in the field of Agricultural Engineering. It is only intended to be an attempt to make an elementary theoretical analysis of the subject by one who has been a sympathetic observer of the trends of development in this field. For the purpose of this discussion the title should be changed to the general theme of the place of Engineering Experiment Stations in the full development of the Agricultural Engineering profession.

Argicultural Engineering

The whole profession of engineering is struggling for a place of maturity among the more stabilized and in some places more highly respected professions. Agricultural Engineering is one of the more youthful branches of the profession. Its youth gives it the virtues of enthusiasm and freedom from prejudice on the part of its members. It also poses problems of interest and importance for the consideration of its professional Society.

The American Society of Agricultural Engineers has been concerned with the matter of accrediting curricula in the various colleges and universities. The recent tentative solution of this problem by obtaining representation on ECPD accrediting committees and working cooperatively with other engineers and engineering educators seems logical. The matter of legal registration of Agricultural Engineers before the various State Examining Boards is another problem requiring careful consideration. It is hoped that a solution of this situation may come about through finding a means of cooperative action.

Professionia Development

Because the whole profession of engineering is relatively young and because Agricultural Engineeing is one of the more recently established branches of the profession it may serve us well to examine the basic elements necessary for the full development of any learned profession.

A well developed profession is the product of the work of specially equipped men. Special knowledge determines it identity. Motives or ideals give it spirit and direction. Ignoring the risk of over-simplification it is suggested that a truly professional motive should result in an intense feeling of compulsion leading to three forms of expression.

1. The urge to improve knowledge.
2. The urge to share this knowledge and its benefits.

* Presented at the 55th Annual Meeting, A.S.E.E., Minneapolis, June 18–21, 1947.

3. The urge for recognition among all men.

The Urge to Improve Knowledge

A profession is in its first process of development when its members are zealously searching for ways in which its special knowledge may be extended and improved. Professional men are, therefore, usually alert and responsive when asked to discuss the educational program of their particular calling. Each year the leading members of the various professional societies add to the volume of significant information which constitutes the knowledge peculiarly theirs. This compelling motive keeps the profession alive, and is therefore a primary necessity for professional existence.

The Urge to Share Knowledge and Its Benefits

Possession of the most profound knowledge of a particular subject field by those in a given group, however, has never earned for them the dignity of being a profession. A profession comes into being only after this knowledge is used for the benefit of others. The desire to share knowledge results in the two cumulative rewards: first, that of creating the best conditions for its own increase, and second, by making its values more universally recognized. We have, therefore, created professional societies to furnish an ideal place for sharing knowledge of new developments with others in our own areas of interest. The practice of the profession consists of making our knowledge useful in the lives of others. The value and significance of the service to others is the element which gives tone and dignity to the profession and justifies its existance.

The Urge for Status Among All Men

The members of any professional group are ill at ease so long as they feel other learned men do not appreciate the true value of their services. The whole engineering profession is in that state of development where it is not assured of this high esteem.. Because recognition has not yet been universally accorded we hear the complaint that few people know what the Engineer does and very few are willing to pay the engineer full value for his services as a fair return for his cost of education.

In this simple explanation of professional development please note that each of the basic urges leads to the next following. It is impossible to start with the third and work toward the first. When knowledge is increasing rapidly and is being liberally shared with others "status" among men will grow and the compensation of the practitioner will increase.

The Place of the Engineering Experiment Station

What is the place of the Engineering Experiment Station in this process of professional growth of Agricultural Engineering? The Engineering Experiment Station is the ideal agency to carry on the process of extending and improving knowledge in Agricultural Engineering. In the education of the student it is known that we teach best by example. If we expect our graduates to extend and improve their knowledge in professional work we should, by example, be enthusiastically carrying on the same process. One of the most obvious places to carry on this process is in the activities of the Experiment Station. If full development

of the profession is only possible through sharing with others the benefits of our knowledge we should be working on projects which are helpful to other groups of men. In our case these are the numerous groups who are vitally concerned with Agriculture from weather, soil and seed, to human food and manufactured product. It would then naturally follow that most of our projects would fall in the general classification of applied rather than fundamental research. The best and probably only way to obtain "status" is by becoming an important contributor to the solution of problems which confront other people. By finding some easier or quicker way of doing work or more profitable method of processing or storing our products or creating a more pleasant place in which to live we thereby lift ourselves in the esteem of others. This is the purpose of an Engineering Experiment Station.

Experiment Station Details

How can the Engineering Experiment Station do its best work? If the Experiment Station is to be of maximum value in working out applications in Agricultural Engineering it will be necessary to draw freely from the resources of many other men of science and engineering. Our problems are so interrelated that few really important projects can be adequately studied by drawing upon the resources of single individuals or from only one special interest group. It would seem that Agricultural Engineering problems could best be attacked where it is possible to call upon the resources of the physicist, the chemist, the bacteriologist and other men of science and upon the electrical, mechanical, civil and chemical engineer.

If maximum values to the Agricultural Engineering profession are to result from the activities of the experiment station, projects should be selected which are of vital interest to the people residing within the area of service of the station. There is no engineering school in the United States which is without vital and interesting research questions of particular significance to the welfare of its own region. Agricultural Engineering will have achieved national recognition when it has gained the high respect of the citizenry of each of the various regions. Support will be given agencies which earn respect through such constructive service.

To illustrate this theory we might use the region in which Nebraska is located. The peoples of our area are interested in the development of new machinery which would eliminate or decrease the necessity for "stoop" labor, such as potato harvesting and sugar beet harvesting. The cultivation of castor beans is increasing as an industrial crop. The development of a harvester for this crop would be helpful.

In the building field there is still a great possibility of designing for more economical construction for greater utilization of local building materials and the adoption of some of the newer construction materials to particular conditions in Nebraska. Our combination of wind and sunshine are unusually destructive to paint. Studies of special protective coatings for structures exposed to weather might be appropriate.

In the reclamation field we must move toward better development of wells for irrigation and general water supply. A study of all methods of

land preparation for irrigation would be appropriate for any school located in the upper reaches of the Missouri River Basin. Ingenious erosion control structures have not yet all been conceived.

Rural electrification is still in the expanding period in our region. The possibilities of greater use of this power have scarcely been touched.

We in Nebraska believe that small communities have special social values and that it would be a national calamity if they were lost. They can best be preserved by making it possible to have conveniences more readily available to the citizens outside the larger towns and cities and thereby make living more interesting and pleasant.

This is not an exhaustive listing of potential possibilities but they illustrate the fact that a combined engineering attack should be made upon them. The Agricultural Engineer, if he is to develop himself and his opportunities, must join with all men of science and engineering in serving his region.

It should be plain that the place of Engineering Experiment Stations in Agricultural Engineering extends throughout the whole pattern of development of the profession including the responsibility to expand and improve knowledge, the sharing of knowledge so that all may benefit and finally in creating the condition where engineering may deserve a position of high esteem among all men.

A Curriculum for Metallurgical Engineering*

By J. P. SPIELMAN

Professor of Metallurgy, Montana School of Mines

It is a genuine pleasure to be in attendance for the first time at a national convention of our society. It would also be a pleasure to pose this afternoon as a great educator and student and to promise you a scholarly paper dedicated to the theory of higher education. But I can do none of these things and must plead guilty to being a neophyte in the field of education and guilty to being largely a student of industry and of industrial research. As a result, my presentation of the subject "Curricula for Metallurgical Engineers" must be partly from the standpoint of an outsider and partly from the standpoint of one so new to the great profession of teaching that he does not recognize sacred ground when it is seen.

It is advisable to make clear at the outset that this discussion is concerned with curricula leading to the Bachelor's degree in Metallurgical Engineering; curricula designed primarily to train men to enter the profession directly or to continue their studies in the graduate school.

I wish to make clear that there is no *curriculum* for metallurgical engineering. Like all other engineering problems many acceptable solutions are possible, each accomplishing the desired result. This is because our educational institutions differ widely in equipment and personnel, and still more widely in raw material. The basic problem in all institutions, however, is "What shall we teach and how shall we teach it?" This is not a new problem but the age old one, aggravated by the great social and technological changes of the times. It is the simple plant problem of the best process to convert a given raw material into a given end product, complicated to some degree by the desirability of retaining the individual characteristics of the raw material.

Let us for the moment relegate this problem to the field of engineering, reduce it to its simplest form, solve the component part and then inject into the solution the human element, the individualisms of the raw material and the processor.

The production of any material is predicated on a market, a demand for a material of relatively definite specifications to meet a specific need. This is equally true of our educational processes in certain fields and we are justified in assuming that a demand does exist for metallurgical engineers and that it will continue to exist. The first portion of our problem then is to determine the general specifications of our product. Considering ourselves, the educators, as the processors, it is not for us to say what specifications our product should have but rather for industry, the customer, to specify

* Presented at the 55th Annual Meeting, A.S.E.E., Minneapolis, June 17–21, 1947.

(neglecting momentarily the graduate school). Many articles and surveys have been published on this subject during the past several years and recommendations of our society are an authoritative guide. I wish to make a brief presentation of these specifications, however, from another source because it comes directly from industry independent of any organized survey. The following specifications for the newly graduated metallurgical engineer are taken from several hundred personal communications and interviews with industrial leaders and practicing metallurgical engineers:

1. He must be able to speak and write the English language correctly and with reasonable fluency.
2. He must be thoroughly grounded in the basic sciences and the fundamentals of metallurgy and engineering.
3. He must be inculcated with the engineering approach to a problem and the engineering method of solving it.
4. He must have a knowledge of the functioning and the problems of the society of which he is a part and he must be willing and able to assume more than an average share of the responsibilities of citizenship.
5. He must have a knowledge of the field of human engineering.
6. He must have imagination, initiative, ingenuity and integrity.
7. He should enter industry with some understanding of the economic structure of American business.
8. He must be willing to work for his place in the profession, learning as he does so.

These specifications are general over the nation with no differentiation by geographical location and no differentiation by fields or branches of the industry. It will be noted that in the above requirements there is no mention of the specific ability to *do* certain things. This, I believe, is a most significant fact and is a definite trend throughout industry—a radical change from the years past when we were forced to take much of the students time for the presentation of "bread and butter courses" in order to insure him employment. All of our larger metallurgical enterprises have inaugurated training programs of one type or another. Of the programs of this type which I have examined during the past two years, the shortest covered a period of three months and the longest a period of nearly three years. This is a positive indication that industry prefers to teach the "how" of metallurgy. The only exception to the above seems to be small operators and an examination of their plants reveals that they hire few, if any, new graduates, preferring to hire men with several years of industrial experience.

Another definite and significant conclusion can be drawn from these specifications. Scholastic standing has and always will be an important criteria in the evaluation of a graduate but it is not the sole criteria and in many cases is not considered the most important. Industry holds, and rightfully so, that the graduate with the greatest engineering promise is the man possessing the greatest number of the desired characteristics all to a reasonable degree. In other words, the student who might have had an A but took a B in order to devote time to experimentation in student government, forensics, and music; in order to devote time to the study of current labor legislation and labor relations

and to do library work in allied fields not covered in the classroom. Industry is going much deeper into the qualifications of its potential metallurgical engineers than the veneer which is indicated by a cold scholastic average. It is seeking the man with the solid foundation on which to build a professional career, the man who can earn and hold the respect of his fellow workers and his fellow citizens. Industry no longer looks to the colleges for a supply of technicians but for a supply of educated individuals from which true professional engineers can be developed.

This phase of our problem intrigues me because of my years of industrial training and if time permitted I could speak about it endlessly but I would like to close this discussion of our end product with the words of a dear friend, one of the outstanding metallurgical engineers of the West. While discussing these problems with him some 18 months ago I hastily outlined some of the changes I contemplated in our scholastic program. I must have waxed rather enthusisastic because when I stopped for lack of breath he took advantage of the pause to say, "That sounds very interesting and I am sure will prove successful, but remember, *we in industry make the engineer*, YOU SHAPE THE MAN!"

In the period since this interview my studies of industry's requirements of new graduates have continued and have covered the United States and much of Canada and Mexico. The further I go into the subject the more I am convinced that this statement reduces this phase of our problem to the simplest terms. Not just the shaping of the character of the man but the shaping of his mind—his imagination—his professional ethics—his judgment—his tolerance—and the shaping of the foundation on which industry will erect the structure which is the professional metallurgical engineer. This then is our job.

Before deciding on the processes by which we will shape this product we must first examine our raw material—the individuals entering our colleges and whom we must develop into potential metallurgical engineers. I do not believe that our veteran students pose a special problem. It is unfortunate that at this time of great social and technological changes, with the moral obligations on our educational institutions greater than at any time in history that the physical problems resulting from the veterans return should be of such magnitude that in many cases they mask the basic problems of education. Most of the problems of the veteran student are physical; housing, classroom and laboratory space, equipment, staff, and personal problems aggravated by the age and experiences of the student. Educationally, however, they are the product of our secondary schools and while they will, to some extent, affect the "How to teach" portion of our problem they do not alter the "What to teach." We must also, in long range planning, and I believe all curriculum planning should be long range, consider the veteran class of students as temporary.

We are all familiar with the educational procedures of our secondary schools and although we all feel that they should produce for us a tailor made product we must realize that this is impossible. To briefly restate our problem we must accept as our raw material both young and older students, expecting them to be weaker

in cultural subjects, especially English, broader in their scientific horizons and in their knowledge of world affairs, more independent in their thoughts and actions and in all cases eager for technical training and somewhat resentful of the required cultural and Humanistic-Social training. From this raw material we must shape a man grounded in the sciences, in his responsibilities to society and possessing all the traditional characteristics of an educated person.

There are hundreds of ways to reach this objective and I would not presume to offer a minutely planned fool-proof solution adaptable to all institutions and all individuals. I wish to present, however, a solution to the problem which I believe embodies all the basic elements in a balanced relation one to another. Time will not permit a detailed discussion of all elements or all the reasons for the solution. This is not necessary for like all problems, when the various elements are seen clearly, the solution is obvious and simple. I propose the following curriculum under six major headings and beg your indulgence in my deviation from the conventional sub-headings.

Group I. Basic Engineering Subjects—15.0% of total required hours.

These should include drawing, descriptive geometry, surveying, topographic drawing, applied mechanics, hydraulics, strength of materials, and electrical engineering.

Group II. English—6.0%.

This should include literature (both technical and classic), composition (written and oral) and technical and business writing. Courses in public speaking have been included eleswhere. These courses should be very carefully planned to make them interesting and definitely should not be a rehash of high school grammar courses. Proper presentation of these courses is a real challenge to our English departments and they must meet it.

Group III. Humanistic-Social Group—15.0%.

This group should be fluid to allow for adjustments to meet the needs of individuals. In general, I like to balance roughly six sub-groups as follows: History—20%; Economics—20%; Political Science—20%; Sociology—20%; Psychology—10%; Public Speaking—10%. I like public speaking included as an integral part of this stem. Where better to study parliamentary procedures than concurrently with political science, or debate than concurrently with economics or sociology or history? I also believe that into this stem should be woven the hours for a foreign language by adjustment of the balance or if necessary or desirable by adding hours to the schedule.

Group IV. Basic Sciences—35.0%.

These should include: Chemistry—45.0% and the courses should cover General Chemistry, Qualitative and Quantitative Analysis, Physical Chemistry, Electro-Chemistry, Organic Chemistry, and Chemical Thermo-dynamics. Physics—25.0% and should include at least one good course in Modern or Advanced Physics to include the theory of radiations, electronics, etc. Mathematics—30.0%; and may I say that there is never too much mathematics in a curriculum for metallurgical engineering.

In connection with the basic sciences I will risk my professional head and express the wish that it were possible to include some hours in the basic science of biology in all engineering

curricula. It does not seem to me that omission of some training in the great science of life is compatible with true education.

Group V. Mining and Geology—6.0%.

These should include Historical Geology, Mineralogy, and a survey of Mining Practice and Mining Law. The courses should be planned to furnish a knowledge of the earth on which we live and to broaden the students knowledge of the general field of the mineral industry.

Group VI. Metallurgy—23.0%.

I should like to dwell for a short time on this portion of the curriculum because it is with the subjects of metallurgy that we are most directly concerned. The first question is "What shall we teach?" and in direct answer to this question I say with all the sincerity I possess, "It does not matter so long as we avoid over-specialization as we would a plague and so long as it is truly WELL TAUGHT!" Oviously, no two people would present the same material even under the same course title and the same course description. Obviously, no two colleges will be identically equipped and staffed. I believe, however, in a more or less general guide on the distribution of time to the various fields of metallurgy. All students should have a good introduction to general metallurgy, metallurgical calculations and metallurgical laboratory procedures. This should be allotted about 1/6 of the total time. Another 1/6 of the time should be allotted for training in the great field of Mineral Dressing and another 1/6 of the time for such courses as Fire Assaying, Thesis, seminar and plant study. The remaining 1/2 of the total time should be equally divided between extractive and adaptive subjects. The extractive subjects must include all of the processes, hydro-, pyro- and electro-metallurgical. The adaptive courses must include physical metallurgy, metallography, ferrous and non-ferrous alloys and heterogeneous equilibrium. All of these courses must be held to fundamentals in order to economically utilize the students time and to avoid teaching much that will be obsolete by the time the student begins to practice his profession.

A word at this point about fire assaying and the time allotted to it. I maintain that it is not our function to train assayers and furthermore that the determination of gold and silver values is basically just another quantitative chemical determination. I also hold, however, that a well planned and well taught course in fire assaying can and should be a most effective introduction to pyro-metallurgy and that the time devoted to it is justified for this reason and for this reason alone. The effectiveness of the course depends entirely on how and by whom the course is taught—a competent metallurgist or an assayer. My own recent experience has proved the value of a proper course in fire assaying beyond the shadow of a doubt.

In teaching the processes I believe that we must constantly remind ourselves of industry's part in the development of the engineer. Let us leave to them the portion of the training which is rightfully theirs. Fifty years ago the problem of presenting the processes was a relatively simple one. The number of industrial metals were few and they were studied one at a time with all the details of their respective processes. Today, with our almost endless list of industrial metals

this is impossible and undesirable. Impossible because of lack of time and undesirable because of rapidly changing processes. But the properties of metals and their compounds and the fundamental principles of our basic processes do not change. It seems desirable then to recommend the teaching of extractive metallurgy, or as I prefer to call it "chemical metallurgy," from the standpoint of the unit processes emphasizing the basic scientific principles of each. I frequently liken the metallurgical engineer to a painter, who with a few basic colors selects those he needs, blends them together and produces a new color—so the metallurgical engineer with a few basic processes selects those best suited to the solution of a given problem, combines them and a complete new process or plant results. Many problems should be presented with such a course, first to drive home the application of the principle and second because the metallurgical engineer who cannot calculate has lost the race before the starting gun has been fired.

The subjects in adaptive metallurgy must be sufficiently broad to draw heavily on the students previous training in physics and mathematics. How this is to be accomplished is an individual problem but the student must complete the courses with a thorough understanding of the basic principles of equilibrium, the nature of metals and alloys and some knowledge of modern tools for research in this field, *i.e.*, radiography, diffraction patterns, the electronic microscope, etc.

I believe implicity in the undergraduate thesis. This is a milestone in the student's career, a finalé to his training which he prizes highly. There is, however, *danger* in this course. We must exercise the greatest care that we do not try to make the student run before we have taught him to walk. Many students suffer severe frustration over a thesis problem through no fault of their own. Original and independent research is most difficult for the average undergraduate because many subjects basic to his problem are being studied concurrently with the research. I believe that thesis problems should be carefully planned in advance so the student can be led without his realization to a definite and *positive* solution accumulating some negative information along the way. The problem and its solution should be planned to accomplish certain definite things aside from the actual writing of the report. (1) It should fire the student's imagination and create a thirst for new knowledge. In other words it should awaken a true research sipirt. (2) It should teach him to see and record that which has actually occurred and not that which is expected or hoped for. (3) It must teach the value of negative information as well as the value of positive information. (4) It must make him feel that he has contributed something definite to the world's store of knowledge.

During my years of industrial research I had three problems with young engineers bearing on these points. The first was to train them to see and record that which had actually occurred—not the hoped for occurrence. I believe this is the result of too many cut-and-dried experiments where the answer or result is known before the experiment is performed and anticipation masks true observation. I should refer to these as exercises, not experiments. The second problem was

the careful accurate and complete recording of negative information. The old answer. "It didn't work, so why bother," was invariably given. This reflects a lack of professional training, a lack of the true research spirit. They have no thought for the people or the work which is to follow. The third great problem was imagination, or rather a lack of it. Much can be done to develop imagination in a carefully planned thesis, in fact, throughout the entire curriculum and it is here that we must cease to consider our students as raw material and delve into the personal traits of each individual in order to develop to the fullest the rampant imagination present in every youth.

How to do this specifically and how to teach in general are questions I cannot answer. I know, however, that every teacher must, in his own way, do more than teach, he must inspire at all times. Each of us must exemplify in every way and at all times the true American way of life if we are to shape the men our students will become. Research is one way to accomplish this. A sage, long since forgotten, defined teaching as "seeking and transmitting truth." In my simple one track mind I have never been able to separate the search from the transmission or the transmission from the search—they are as inseparable as the gold dust twins. Any curriculum not constantly enriched by research is drab indeed and doomed to failure. Any teacher who does not inspire himself and his students by research is in a rut and the only difference between a rut and a grave is in the depth. Let us not have in our metallurgy departments teachers who die at 28 and are buried some fifty years later.

In connection with teaching I wish to mention two more courses, the *most* important to a successful engineer but not listed in the curriculum. They must, however, be there. These are courses in "Judgment" and "Tolerance." With these subjects mastered the metallurgical engineer will be a classic success, without them he will be a monumental failure. They must be taught in every course, in every classroom and laboratory, and by every teacher. In addition to teaching them we must live them every minute of every day. We all recognize that all the student learns from his teachers is not passed out in the classroom as information, much is in the very atmosphere of the college, and in the personality of the teacher. These things all teach judgment and tolerance, fire imagination, develop consideration for others, gracious living, the enjoyment of life, and instill a real appreciation of a professional career.

Time does not permit a longer discussion of these points and many more must be omitted. I wish to mention briefly only a few more matters. Our curricula must be sufficiently fluid to allow each student some selection of subjects within certain broad fields but in such a way that the balance is maintained. It must also be sufficiently fluid to allow us to accommodate the outstanding student, the man born to research. Of this student I say, "Take him to your breast and nurture him as you would an orchid for in his development lies the great compensation of teaching, and still more important, he is the insurance for the future of our profession and our Country." These men should be destined for the graduate school which is,

of course, the place for specialization and research. I do not propose a discussion of the graduate school except to say that the above curriculum is an excellent preparation.

This curriculum does not present the problem of what to include but rather of what to exclude and to accomplish our objective we must be constantly weighing each course and all the subject matter therein, ruthlessly *eliminating* any material when we discover something else will serve our purpose better. I emphasize "eliminating" because we are all by nature possessed of the weakness to add and never to subtract. We must remember that the only way to add new cordage to a rope of maximum size and length is to remove some of the old.

We all recognize that the world has entered into a new technical era. I believe that the program outlined above will adequately prepare our metallurgical engineers to take their rightful place in this new world. I also believe that the time to begin preparing them for this place is now! It is true that there is a great demand for engineers at the present time and the report of the committee on man-power indicates that our engineering colleges are in a seller's market. But this will not always be true, and whether it is or is not, our job is still to produce the best possible potential metallurgical engineers. We must shape an educated man from which industry will shape a professional engineer.

A Modern Tower of Babel

By J. ANTONIO THOMÉN
Professor, University of Santo Domingo, Dominican Republic

Thousands of years ago, so the story is told, men, in their desire to reach Heaven, conceived the idea and undertook the task of building the Tower of Babel, and, as a punishment for their boldness, Jehova brought confusion among them by changing their language into different ones, so they could not have understanding among themselves, and so they failed in their task. In this story "Heaven" may be construed as *Happiness Through Understanding*.

Many years after that experience men decided that the pursuit of happiness is one of their inalienable rights, but much has been said and little done to attain it through understanding.

It is very unfortunate that men have given up hope or the desire of an universal language as Esperanto was once expected to become. It seems that the adoption of an existing language is impractical because of rivalries among peoples. It is also a pity that Latin was dropped long ago as the language of learned men.

There is no doubt that great progress in the sciences and mathematics was made in the Renaissance because men of different nations communicated their discoveries to others who would develop them, and the unfortunate incident between Newton and Leibnitz in the field of mathematics can be considered as an isolated case caused by Newton's reluctance to publish his early discoveries.

Whatever motives led Newton to keep his discoveries to himself or induced Leonardo da Vinci to write in hieroglyphics, it is interesting to note that Descartes and Newton published the Discours and the Principia through the advice or efforts of others. There seems to have existed a sort of selfishness, pride or uninterested greed in men of science who treasured their discoveries as modern inventors treasure their inventions. It is possible that this attitude still exists in our days, but we must see to it that whatever is published shall not be left to be rediscovered in our time.

There is no doubt that much happiness can be attained through understanding among men. Great benefits can also be obtained. But understanding requires a common language and engineers should have a common language of symbols, definitions, units and conventions.

The American Society for Engineering Education has been very foresighted to invite observers from the Latin American countries to its Annual Convention of this year in Minneapolis. This is an excellent way of seeking understanding among the men of the engineering profession who should have a common language.

Therefore, for the benefits which

will obviously be obtained thereby, it is hereby moved:

That the American Society for Engineering Education Recommend the Adoption of International Normal Symbols for the Different Subjects Treated by Engineers; That it Promote the Publication of Comprehensive Standard Books on the Said Subjects; and That It Start and Follow a Movement for the Use of the Metric System of Units in All the Subjects Treated by Engineers, as It Is Used in Physics, in Electrical Engineering and in Laboratories.

Many motives can be brought forth to add weight to this motion. I shall endeavor to be brief by using a few illustrations.

One motive is exemplified by the mission of Mr. S. S. Steinberg, as explained in the paper presented by him in the 54th Annual Meeting of the S.P.E.E.: the carrying out of this motion is a first step toward the attainment of the purposes of his trip to South America. American books and periodicals will be more widely read by Latin American engineers when so much decipherment become unnecessary and, this being eliminated, a wider interchange of publications, information and knowledge among engineers will result. This will also promote the study of one another's languages, thus making possible the exchange of engineering professors among different universities and countries.

A second motive for the present motion is that it affords the solution to the difficulties encountered in the "Coordination of Teaching in Physics and Engineering Mechanics." In the article and discussions published in the JOURNAL of April 1947 under the title just quoted, the difficulties that the student goes through in passing from the study of Physics to that of Mechanics are mentioned. The experience is well remembered by all those who had to "unlearn" their Physics (as Mr. Schubmehl puts it). On this question Mr. Potter puts his finger in the sore spot when he writes: "In Physics we are afflicted with the necessity (of teaching Metric as well as English system)." The correct statement should have been: "In Mechanics we are afflicted with the use of the English system."

A third motive has its origin in the fact that engineering education is ever tending to be more humanistic and the engineer must therefore have more expedient means for deepening his information by studying the matter of his subjects from different sources, written with the same symbols, sign conventions and units as he studied the elements of the subject while in school, lest he has to "unlearn" that which he already knows, before he can become proficient in any one field.

The chapter on the Slope Deflection Equations which is found in practically all the books on Reinforced Concrete and on the Theory and Design of Structures may be taken as an example to make this point clear. The difference in the presentation by the different authors usually consists in a new convention of signs, a different figure used in the derivation of the equations and various changes in the exposition by means of which the author complies with the usual "This book or any part thereof must not be reproduced. . . ." On the other hand, many important points in the

original sources are left out in the new presentations, as happened, to name an example, in the case of the semi-graphic solution of compound stresses given by Rankine in his Applied Mechanics, a method which is so appropriate for visualizing purposes.

It is hoped that this motion, which to some may appear as an insurmountable mountain, will be received in good heart and that the modern engineers may set the example by building this modern Tower of Babel and thus the Lord, with his blessing, reverse the judgment of the Terrible God of the Ancients.

New Members

Arendt, J., Instructor in Structural Engineering, Fenn College, Cleveland, Ohio. S. M. Spears, G. H. Smith.

Bassar, Nicholas, Instructor in Civil Engineering, Montana State College, Bozeman, Mont. E. R. Dodge, R. C. De Hart.

Boeck, Ralph E., Associate Professor of Civil Engineering, Marquette University, Milwaukee, Wis. O. N. Olson, R. J. Smith.

Budde, Francis J., Assistant Coordinator, Industrial Coordination, University of Detroit, Detroit, Mich. W. P. Godfrey, D. C. Hunt.

Butterfield, Robert E., Associate Dean, Robert College, Istanbul, Turkey. F. L. Bishop, Nell McKenry.

Cameron, A. E., President, Nova Scotia Technical College, Halifax, N. S. F. L. Bishop, Nell McKenry.

Carr, T. D., Dean of Engineering, University of Kansas, Lawrence, Kan. K. B. McEachoon, M. M. Boring.

Cason, Frank L., Coordinator of Placement (Assistant Professor), Purdue University, Lafayette, Ind. A. A. Potter, W. A. Knapp.

Chukwuemeka, Nwankwo, Assistant Professor of Mechanical Engineering, Howard University, Washington, D. C. A. E. Richmond, D. E. Howard.

Clement, William D., Instructor in Mechanical Engineering, University of New Hampshire, Durham, N. H. O. T. Zimmerman, E. H. Stolworthy.

Cobb, R. N., Assistant Professor of Mathematics, Worcester Polytechnic Institute, Worcester, Mass. H. Rice, R. K. Morley.

Cross, Edward F., Assistant Professor of Engineering, Walla Walla College, Walla Walla, Wash. S. J. Tracey, G. P. Rettig.

Dorman, Stuart C., Assistant Sales Manager, College Dept., McGraw-Hill Book Co., New York City. James S. Thompson, Nell McKenry.

Ekse, Martin, Instructor in Drawing, University of Wisconsin, Madison, Wis. R. R. Worsencroft, H. D. Orth.

Felgar, Robert P., Instructor in Engineering Mechanics, University of Texas, Austin, Texas. W. R. Woolrich, B. E. Short.

Flitner, David P., Instructor in Mechanical Engineering, Pratt Institute, Brooklyn, N. Y. N. S. Hibshman, R. E. Lake.

Freedman, M., Lecturer in Civil Engineering, George Washington University, Washington, D. C. C. H. Walther, F. M. Faikes.

Frishe, W. C., Professor of Chemical Engineering and Metallurgy, Grove City College, Grove City, Penna. C. S. Hoyt, C. A. Basore.

Gallo, F. J., Instructor in Structural Engineering, Fenn College, Cleveland, Ohio. G. H. Smith, S. M. Spears.

Glass, Robert H., Instructor in Engineering Mathematics, University of Colorado, Boulder, Colorado, C. A. Hutchinson, W. Raeder.

Gleason, George S., Professor of Engineering, University of Massachusetts, Fort Devens, Mass. J. D. Swenson, G. A. Marston.

Glennan, T. Keith, President, Case Institute of Technology, Cleveland, Ohio. W. E. Nudd, Elmer Hutchisson.

Glover, L. E., Lecturer in Engineering, Woolwich (England) Polytechnic, London S. E., England. W. A. Holt, R. Pattison.

Hamm, A. S., Assistant Professor of Civil Engineering, University of Maine, Orono, Me. W. A. Evans, F. M. Taylor.

Harris, E. C., Associate Professor of Structural Engineering, Fenn College, Cleveland, Ohio. S. M. Spears, G. H. Smith.

Helwig, W. F., Associate Professor of Electrical Engineering, University of Texas, Austin, Texas. W. R. Woolrich, V. S. Doughtie.

Hilding, Winthrop E., Assistant Professor of Mechanical Engineering, University of Connecticut, Storrs, Conn. H. W. Butler, C. H. Coogan.

Irwin, D. E., Assistant Manager, Technical Personnel Division, General Electric Com-

pany, Albany, N. Y. M. M. Boring, A. C. Stevens.

JEFFRIES, R. J., Instructor in Electrical Engineering, The John Hopkins University, Baltimore, Md. W. B. Kouwenhoven, J. Thompson.

JOHNSON, J. STUART, Assistant Dean, Professor of Electrical Engineering, University of Florida, Gainesville, Fla. F H. Pumphrey, R. A. Morgen.

KESSLER, CHARLES J., Assistant Professor of Engineering Drawing, Kent State University, Aurora, Ohio. C. M. Stone, W. E. Nudd.

KIRCHER, C. E., JR, Professor of Chemical Engineering, Rose Polytechnic Institute, Terre Haute, Ind. D. B. Prentice, F. L. Bishop.

KORSMEYER, F. B., Assistant Industrial Relations Manager, Research and Development Dept., Socony-Vacuum Labs., Woodbury, N. J. P. W. Boyton, A. G. Conrad.

LONGO, CHARLES V, Instructor in Electrical Engineering, Rutgers University, New Brunswick, N J. S. P. Owen, M. T. Ayers.

LUCAS, ROBERT L., Instructor in Electrical Engineering, University of Pittsburgh, Pittsburgh, Pa. P. E. Rush, R. C. Gorham.

LYON, J. A. M., Associate Professor of Electrical Engineering, Northwestern University, Evanston, Ill. J. F. Calvert, E. W. Kimbark.

McGUIRE, C. W., Assistant Professor of Economics, University of Colorado, Boulder, Colo. C. L. Enkel, C. A. Hutchinson.

MISER, W. L., Head and Professor of Applied Mathematics, Vanderbilt University, Nashville, Tenn. J. H. Zant, W. W. Graham.

NELLIS, A. A., Instructor in Engineering Drawing and Descriptive Geometry, Ohio University, Athens, Ohio. E. T. Gaylord, N. D. Thomas.

O'ROURKE, RALPH W., Associate Professor of Engineering, University of Massachusetts, Fort Devens, Mass. J. D. Swenson, G. A. Marston.

PENNEY, GAYLORD W., George Westinghouse, Professor of Engineering, Carnegie Institute of Technology, Pittsburgh, Pa. B. R. Teare, W. N. Jones.

PIPER, WILLIAM E., Assistant Professor of Mechanical Engineering, University of Deleware, Newark, Del. D. L. Arm, J. I. Clower.

POZNANSKI, MITCHELL C., Instructor in Chemistry, University of Detroit, Detroit, Mich. H. Gudebski, C. E. Duncombe.

RATTERRES, W. B., Assistant Professor of Engineering Drawing and Mechanics, Georgia School of Technology, Atlanta, Ga. M. P. Harris, F. C. Bragg.

REBERT, CHARLES J., Instructor in Chemical Engineering, University of Detroit, Detroit, Mich. H. Gudebski, C. E. Duncombe.

ROGERS, ROBERT H., Representative, College Dept., McGraw-Hill Book Co., New York City. James S. Thompson, Nell McKenry.

SCHRAUT, K. C., Associate Professor of Mathematics, University of Dayton, Dayton, Ohio. A. J. Holian, A. R. Weber.

SCRANTON, W. W., Representative, College Department, International Textbook Company, Scranton, Penna. L. W. Tice, S. Baker.

SEEGER, JOHN C., Assistant Professor of Mechanical Engineering, Louisiana Polytechnic Institute, Ruston, La. H. L. Henry, B. T. Bogard.

SKINNER, WILLIAM J., Assistant Professor of Mechanical Engineering, Cornell University, Ithaca, N. Y. L T. Otto, E. R. Watt.

SQUIER, WILLIAM W., Director of Educational Research, National Air Council, 1602 Edgewood Drive, Royal Oak, Mich. F. L. Wilkinson, C. T. Reid.

STAMPS, T. D., Professor of Military Art and Engineering, U. S. Military Academy, West Point, N. Y. B. W. Bartlett, D. J. Gatchell.

STAPLETON, H. N., Research Professor of Agricultural Engineering, University of Massachusetts, Amherst, Mass. G. A. Marston, M. E. Bates.

SWEARINGEN, LLOYD E., Professor of Chemistry, University of Oklahoma, Norman, Okla. R. V. James, F. G. Tappan.

VACCARO, MICHAEL J., Student Counselor, Guidance Center, John Carroll University, Euclid, Ohio. H. R. Young, R. R. Slaymaker.

VEIRS, STEPHEN D., Instructor in Industrial Engineering, Ohio State University, Columbus, Ohio. P. N. Lehozky, R. S. Green.

VINE, WILLIAM A., Instructor in Mining Engineering, Missouri School of Mines, Rolla, Mo. C. L. Wilson, J. D. Forrester.

VOGELBACKER, R. E., Representative, College Department, International Textbook Com-

pany, Scranton, Penna. L. W. Tice, S. Baker.

WAGNER, E. J., Assistant Professor of Electrical Engineering, Illinois Institute of Technology, Chicago, Ill. T. J. Higgins, G. F. Levy.

WANER, N. S., Instructor in Heating, Temple University, Philadelphia, Penna. J. A. Goff, G. H. Bush.

YAROCH, WILLIAM L., Instructor in Chemical Engineering, University of Detroit, Detroit, Mich. H. Gudebski, C. N. Duncombe.

89 new members, 10-3-47

Necrology

William Elgin Wickenden

The death of William Elgin Wickenden, fortieth President and eighth Lamme Medalist of the American Society for Engineering Education, brings to an untimely close one of the most brilliant and fruitful careers in the history of engineering education. Dr. Wickenden's death, at his summer home at Jaffrey, New Hampshire, occurred on September 1, 1947, but a few hours after his retirement as President of Case Institute of Technology, a post he had occupied since 1929. He was approaching his sixty-fifth birthday. He is survived by his wife, Marion Lamb Wickenden, his son William C., and his daughter Elizabeth.

Dr. Wickenden was a native of Ohio, and was awarded the baccalaureate degree by Denison University in 1904. He pursued graduate courses at the University of Wisconsin, and served as instructor at that institution from 1905 to 1909. From 1909 to 1918, he served successively as Assistant Professor and Associate Professor of Electrical Engineering at the Massachusetts Institute of Technology. He then transferred to industry, continuing his career in educational work as Personnel Manager of Western Electric Company from 1918 to 1921, and as Assistant Vice President of the American Telephone and Telegraph Company from 1921 to 1923. These positions broadened his educational experience and brought him into contact with many of the men in engineering education with whom he was later to be intimately associated for the rest of his life.

It was during this period that he made a noteworthy address at the Annual Convention of the Society at Cornell University, in 1923. This address, which showed his remarkable powers of analysis, interpretation, and expression, was made at the time when the Board of Investigation and Coordination of the Society was about to launch its great study of engineering education, and confirmed the belief that Dr. Wickenden should become its director. For the next seven years, he rendered distinguished service to engineering education, through the results achieved by the investigation, which have served ever since as a major influence in setting the general pattern of engineering education in this country.

In 1929, upon completion of the investigation, Dr. Wickenden became President of the Case Institute of Technology, where he served until his retirement. But his service to engineering education did not end with the completion of the investigation. He continued to exercise strong influence upon the ideals and standards of the engineering profession at large. He was one of the founding members of Engineers' Council for Professional

Development, a Fellow and Vice President of the American Association for the Advancement of Science, and Vice President and President of the American Institute of Electrical Engineers. A week before his death, he had been appointed as a representative for engineering on the United States Commission of the United Nations Educational, Scientific, and Cultural Organization, perhaps the crowning appointment of his career. He also served as a member of the two recent committees of 1940 and 1944, on the Aims and Scope of Engineering Education and on Engineering Education After the War, and on the committee which framed the recently adopted new Constitution of the Society.

Dr. Wickenden exemplified in his own career many of the ideals he expressed for his profession, including what he termed a sustaining interest and relationship to national and civic cultural activities. His membership in twenty-five societies and organizations was not merely the act of joining them; he rendered active service as counselor, participant, and leader in their affairs. Dr. Wickenden was noted, among other qualities, for his conspicuous ability as a writer and speaker, and for the clarity and fluency of his expressions. This was not a mere matter of superficial fluency; it was based upon the more fundamental qualities of a quick and virile mind, a great fund of information, the ability to analyze clearly and simply, and to grasp quickly the broader aspects and implications of a great variety of problems. What Dr. Wickenden wrote and said was based upon clear thinking, and the lucidity of his remarks upon knowledge transmitted through accurately chosen words. A study of one of his contributions to the literature of engineering education, of which his "Comparative Study of Engineering Education in the United States and in Europe, 1929," is one of the most outstanding, will reveal an astonishing amount of information, arranged in clear and coherent form, and a discerning analysis of a complex and varied situation, all presented in simple tabulations and clear language.

Dr. Wickenden was a man of fineness and strength of character. He possessed an attractive personality, which impressed itself at once upon those he met. His friendships were staunch and lasting, and he was led to the accomplishments of his career by an impelling motive of puolic service.

Dr. Wickenden's loss is indeed a severe one to education and public affairs in the United States, and especially to engineering education, but the results of his work will continue for many years to constitute the most substantial monument that could be erected to his life and career.

Frederic Lendall Bishop

It was on August 26, 1876, that Frederic Lendall Bishop was born in St. Johnsburg, Vermont. It was on October 11, 1947, that he died in Pittsburgh, Pennsylvania. During this span of busy years he saw the infant Society for the Promotion of Engineering Education grow from a membership of 415 in 1907 (the Society was founded in 1894 with a membership of 156) and mature into the American Society for Engineering Education with a membership of over 5000 in 1947.

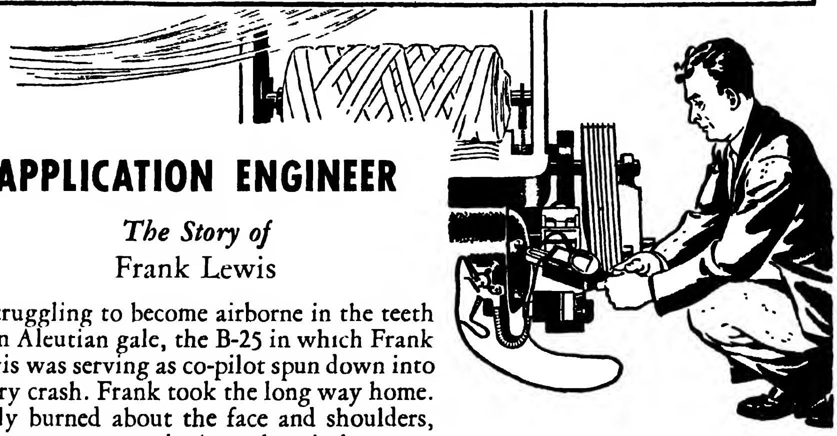
Dr. Bishop obtained his first degree at Massachusetts Institute of Technology in 1898 and his Ph.D. in Physics at the University of Chicago in 1905. He became a member of the Faculty of the Physics Department at the University of Pittsburgh in 1909. Dr. Bishop was Dean of the College of Engineering from 1910 to 1927 and was one of the pioneers in introducing the cooperative system into Engineering Education. In 1927, his love of teaching led him to desert academic administration and return to the class room teaching of Physics. He was Head of the Department of Physics at the time of his death. He was a member of many scientific groups including the American Institute of Electrical Engineers, the Engineering Society of Western Pennsylvania and the American Physical Society. The University Club of Pittsburgh and the Cosmos Club of Washington knew him as a genial member.

Dr. Bishop became a member of the Society for the Promotion of Engineering Education in 1907, a member of Council in 1912, and the Secretary of the Society in 1914. It was not by chance that this Society has unique characteristics; it was because of the keen understanding of this man for engineering education and engineering educators that the characteristics of this Society are as they exist. One senses this uniqueness. It is indefinable. It is Frederic Lendall Bishop.

Dr. Bishop was not one to employ the English language to confuse issues. His methods and his language were direct and to the point. His stand on a point at issue was straightforward, and unmistakable. In a word, he was intellectually courageous. To his hosts of friends all over the world he was kind and considerate, thoughtful and humorous, stimulating and generous.

His passing is a distinct shock to his many friends and a tragic loss to the Society where his advice and counsel would be priceless at this stage of development of the Society.

Campus to GENERAL ELECTRIC



APPLICATION ENGINEER

The Story of
Frank Lewis

Struggling to become airborne in the teeth of an Aleutian gale, the B-25 in which Frank Lewis was serving as co-pilot spun down into a fiery crash. Frank took the long way home. Badly burned about the face and shoulders, he spent two years in Army hospitals.

When he came back to work at General Electric this spring he had been away exactly six years. He had forgotten a lot, changed a lot since the days when, fresh out of the State College of Washington, he had worked on "Test" with G.E.

He took naturally, therefore, to the G-E Rotating Engineering Plan—especially set up to give the veteran a period of familiarization and general orientation.

"The idea worked fine," Frank says. "Any department I was interested in was ready to open its doors for me so I could come in and look it over. When I found a groove that suited me, that's where I would stick."

Frank decided to stick with application engineering. His work proved he was capable of it. On August 1, he took over a desk and drew the first important assignment of his new career.

For your copy of "Careers in the Electrical Industry," write to Dept. 237-6, General Electric Co., Schenectady, N. Y.

After six years of Army service, Frank is today tackling his first assignments as a General Electric application engineer.

Critically injured in a plane crash, Frank spent two years in Army hospitals before resuming his engineering career.

GENERAL ELECTRIC

HYDRAULIC MACHINERY

SAMUEL R. BEITLER
THE OHIO STATE UNIVERSITY
AND
ERIC J. LINDAHL
UNIVERSITY OF WYOMING

This volume was prepared for use as a textbook for a course given to fourth-year mechanical engineering students. Its general content is, therefore, of the survey type and necessarily many of the complex theoretical considerations have been left out in order that most types of equipment which would classify under this heading might be covered. It is intended that the reader will get from the book a general knowledge of the fundamental principles upon which hydraulic machines operate, along with a brief review of fluid mechanics and considerable descriptive matter about machinery as constructed at present.

Where the material is of an analytical nature and examples can be worked out to show the application of the theories, many illustrative examples are worked out and problems are also included.

The descriptive matter is supplemented by many illustrations where such pictures will aid in the understanding of the matter presented.

This material should be of value to the teacher (1) for use in any course similiar to the one for which it was prepared, or (2) as supplementary text for those wishing to show applications of fluid mechanics to actual machines. It should also serve (3) as supplemental material in courses in which certain special machines, as centrifugal pumps, turbines, etc , are studied in greater detail than is possible in a general course

It is probably the first book covering this general field which has appeared in the last ten years.

OUTLINE

The following brief outline will indicate the topics covered and, very generally, the amount of coverage

Properties of Fluids—A brief review of the properties of fluids which affect the performance of Hydraulic Machinery. Methods of computing the value from engineering test apparatus and tables of values of some of these properties in engineering units are included.

Fundamentals of Fluid Flow—A review of the mechanics of fluid flow, based on the fundamental theories of thermodynamics and fluid mechanics.

Pipe and Piping—This section includes a discussion of materials and methods of manufacture of pipes and tubes The properties of pipe materials and the methods of designing piping systems are given

Pipe Line Flow—This gives the latest data available on factors affecting the flow and pressure losses in pipe lines and fittings. Much of this material has been published in the last two or three years and this is the first time that it has been brought together.

Fluid Measurement—The material covered in this part is probably the best in the manuscript and it is not believed that there is any comparable material now available elsewhere Covered are the theory and practice of flow meters, description of all types of metering devices and discussion of general metering problems. The constants given for use with meters are such that flows of all fluids can be computed accurately from the material presented.

Pumps—The general problems of pumping are discussed and different types of pumps are described and their theories discussed. Special emphasis is given to the centrifugal pump since it is probably the most important. However, other types are covered with sufficient completeness to show types available and their possibilities

Hydraulic Turbines and Power Plants—The basic types of turbines are described and their fundamental theories and applications are covered. This chapter was written with the assistance of a practicing hydraulic engineer and covers in general much of the material which is included in much more complete works on Hydraulic Turbines.

Compressible Fluid Flow—This section includes much material on flow of compressible fluids through pipes and meters which is not in any book of this sort and which is of great importance to the engineer who is working in areas where the theory of flow lies in the field of thermodynamics.

Fluid Drives—Description and analysis of performance of various types of fluid drives and hydraulic transmissions which are available for use at present.

218 Pages | **6 x 9** | **$3.50**

IRWIN-FARNHAM PUBLISHING COMPANY

332 SOUTH MICHIGAN AVENUE CHICAGO 4, ILLINOIS

Engineers who know welding are needed

IN developing, designing and building warships of advanced design for the U. S. Navy, the superiority of electric arc welding over other fabricating methods has had ample and convincing proof.

Arc welding is a faster and more economical production method for structural work and metal products of all kinds. Engineers who think in terms of welded fabrication have a greater mental freedom—to depart from the traditional, and design for tomorrow's needs. That is why there will be ever-increasing use of welding in the years ahead. Engineers who understand welded design will be in demand.

Louis S. Newell

President
Bath Iron Works Corporation
Bath, Maine

The U S. S. Frank Knox, latest type U. S Navy destroyer built by Bath Iron Works.

Published through the courtesy of The Lincoln Electric Company, Cleveland 1, Ohio

PRIZE TESTIMONIAL FOR *Automatic Welding*

from our own production experience

When we say automatic welding is *better . . . faster . . . cheaper* — we can prove it right in our own plants. Westinghouse not only makes automatic welding equipment, we're also one of its largest users.

At Buffalo, automatic welding permitted our designers to accomplish these outstanding results in producing the new LIFE-LINE motor: *size and weight reduced 35% . . . power capability increased 116% per pound . . . parts for complete line of NEMA motors reduced from 2,600 to 128 . . . production tripled.*

Once a setup is made, automatic welding becomes a "pushbutton" operation. Even with relatively unskilled labor, every weld is made perfectly. At last, welding approaches machine tool accuracy and speed of work handling.

Westinghouse is the *first* manufacturer to offer complete, "packaged" automatic welding equipment—built, sold and installed as a complete unit. A Westinghouse welding specialist is ready now to help you apply this improved metal-joining technique to your assembly problems. J-85002-A

INVESTIGATE!

Automatic welding is just one of many new or improved electrical techniques for producing faster, cheaper, better. Westinghouse engineers can quickly give you salient facts on others applicable to your industry, including the following:

- **Induction Heating (metals)**
- **Dielectric Heating (non-metals)**
- **Infrared Drying**
- **Electric Furnace Brazing**
- **Resistance Welding**

For details, write or phone your nearest Westinghouse office.

Westinghouse

PLANTS IN 25 CITIES . . . OFFICES EVERYWHERE

MORE PRODUCTIVE POWER FOR INDUSTRY

THE JOURNAL OF ENGINEERING EDUCATION

VOLUME 38 NUMBER 3

Contents for November, 1947

THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION
OFFICERS 1947–48

President

Charles E. MacQuigg, The Ohio State University, Columbus 10, Ohio

Vice President, 2 years

(In charge of general and regional activities)

B. J. Robertson, University of Minnesota, Minneapolis, Minn.

Vice President, 1 year

(In charge of instructional division activities)

C. J. Freund, University of Detroit, Detroit, Mich.

Vice President, 2 years

(Engineering College Administrative Council)

S. S. Steinberg, University of Maryland, College Park, Md.

Vice President, 1 year

(Engineering College Research Council)

F. M. Dawson, State University of Iowa, Iowa City, Iowa

Secretary

Arthur B. Bronwell, Northwestern University, Evanston, Ill.

Treasurer

J. S. Thompson, McGraw-Hill Book Co., New York 18, N. Y.

Assistant Secretary

Nell McKenry, Northwestern University, Evanston, Ill.

Headquarters

Northwestern University, Evanston, Ill.

56th Annual Meeting

Austin, Texas, June 14–18, 1948

Host

University of Texas

Other Wiley books on cover and page 6

". . . More Valuable and Interesting; Less Stupid and Dull . . ."

By C. J FREUND

Vice President, A.S.E.E.

"How did you like the program of conferences at Minneapolis? How do you think the conferences can be improved? We did think that the conferences at the University of Minnesota were pretty good, but how can they be made better at Austin next June?"

That, or its equivalent, is what we wrote to the chairmen of the Society's divisions and committees right after the Minneapolis meeting. The chairmen poured in a flood of suggestions, for which we thank them most heartily. Many of the returns expressed more or less isolated opinions of the individual chairmen, or viewpoints of their associates in the respective divisions and committees, but a number of points were so repeatedly mentioned as to prove a clear consensus of opinion. The divisions and committees apparently agree that:

(*a*) Final programs should be in the hands of the Society's members before they leave their homes for the annual meeting.

(*b*) The schedule of general sessions and conferences should be uniform from day to day throughout the meeting.

(*c*) Invited speakers should be informed long in advance of the meeting, on which day, at what hour and in which room they are to appear.

(*d*) Conferences should be evenly distributed over the half days and evenings of the meeting; if the conferences are largely concentrated within a day, or a day and a half, too many conflicts result.

The Executive Board of the Society met at Pittsburgh on August first and thoroughly went over these suggestions. In order to accomplish the improvements which the chairmen of the divisions and committees had in mind, the Executive Board determined that:

(*a*) General sessions will be held in the morning only, leaving afternoons and evenings for the conferences of divisions and committees.

(*b*) Each division and committee shall schedule no more than two conferences, in addition to luncheon and dinner sessions.

(*c*) The General Conference Committee of the Society shall assign days, hours and rooms for the conferences, luncheons and dinners of the divisions and committees.

(*d*) The Engineering College Administrative Council and the Engineering College Research Council shall each be assigned one general session of the Society and, in addition, shall hold one or two conferences, and luncheons and dinners as the Coun-

cils may elect. The General Conference Committee shall assign days, hours and rooms for conferences, luncheons and dinners; arrangements for general sessions shall be made with the Society's Program Committee.

(*e*) The preliminary program for the Austin meeting will go to press on February first, 1948; the final program will go to press on April 24.

Thus, the Executive Board established a new order for the annual meeting. At first sight these new procedures may appear rigid and drastic. In the long run, they will certainly be conducive to a type of annual meeting which the members of the Society will find very much to their liking.

An important effect of the change is that program making cannot wait until late in April as in other years; the first printing of the program will be issued nearly three months earlier than that.

May we respectfully suggest to the chairmen of divisions and committees that they BEGIN IMMEDIATELY TO PREPARE THEIR CONFERENCE PROGRAMS. Otherwise they will do a rush job under pressure of a deadline, and a conference hastily prepared is likely to be the kind of conference which sends the members of the Society out of doors to take their ease in the shade of campus trees.

The divisions and committees have earned for the Society a gilt edged reputation for stimulating conferences. Members will agree that more of the Society's conferences have been valuable and interesting, and less have been stupid and dull, than in most organizations to which they belong. This reputation must by all means be sustained and expanded.

But the matter of immediate concern for all of us is an EARLY START. It takes at least a month to work up a good conference program; and February first will turn up on the calendar before we are ready for it.

In a week or two we shall begin writing to chairmen of divisions and committees for program data.

And so, now, all together!

Tomorrow's Engineers*

A Reconnaissance Survey

By J. R. VAN PELT

Battelle Memorial Institute

As you know, the announced title of this talk is "Tomorrow's Engineers." You will be right if you infer that I intend to discuss with you the future of engineering as a profession. The discussion will, of necessity, be only a reconnaissance survey; but even a reconnaissance may be enough to give us a good idea of the general location of our future right-of-way.

You should be warned at once, however, that this paper reveals no occult knowledge of what is in store for the profession of engineering. The road ahead, as I shall describe it, may be scanned by any of us who will take the trouble; undoubtedly it is familiar territory to many of you. The prediction of our future course is, therefore, not the main point of this paper. It is only an introduction—a groundwork preceding certain conclusions and recommendations which may affect the program of this Federation and its member societies.

You should also be warned that I am not a reformer. I offer no miraculous panacea for the ills of the profession. It seems to me that what our profession needs is not revolution, but the sincere attention and devoted cooperation of all qualified engineers.

Indeed, I am not so sure that the profession has any very serious diseases. It is young, and may suffer growing pains. It may show the unpredictable awkwardness of a lanky adolescent. It certainly has its annoying ailments. But none of these, it seems to me, should be dignified with the term "disease." On the contrary, if we judge the profession by its results, which after all are the only measure that means much, we have every reason to be proud. What other profession can match it, in reliability of its services, or in rate of improvement? The engineering profession has done a great job of translating the discoveries of science into the useful tools which have lightened man's physical burdens, improved his health and prolonged his life, speeded communication and pushed back frontiers, so that we may hope to arrive at a world-wide culture and civilization in only a fraction of the time which our grandfathers would have thought possible. The engineer has not done these things unaided, but he has been an essential element—probably the dominant element—in this great drama of man's material progress in the western world.

Even in the darkest hour of a technological war, when the power of engineering was focussed on human destruction, engineers had faith to look

*** An address before the Minnesota Federation of Engineering Societies, Minneapolis, February 27, 1947.**

ahead to a distant and brighter day: to see that our conquest of nature, though temporarily applied to warfare, holds for greater values in peace. We see that engineering, by means of the wealth and leisure which it creates, can free the mind as well as the hand; that it gives to the public at large the opportunity to acquire an education, and the time to cultivate those things of the spirit which alone can change the world from a perpetually armed camp into a friendly, prosperous, and progressive neighborhood. No profession has bestowed on mankind more potent opportunities for human betterment.

How has the profession of engineering been able to achieve these great results? Certainly not by adopting an attitude of easy self-satisfaction. Probably no profession has been less given to the insidious vice of complacency. It has always been marked by healthy dissatisfaction with its past, and an amazing readiness to discard a good technique in favor of a better one. Some years ago the production engineers of a Chicago newspaper scrapped a battery of nearly new presses in the pink of condition, merely because they were too slow. Each of these machines could turn out the amazing number of 33,000 complete newspapers per hour, but the publisher would not give them floor space because other presses had become available, through research and engineering, which could turn out more than 50,000 papers per hour. Similarly, in the aircraft industry it is a commonplace that every new airplane design is obsolete before it is off the drawing board. In our profession which so cheerfully discards the good for the better, it is only natural that we should look eagerly to the future betterment of the profession itself without implying any criticism of the past.

The Road Ahead

Let us, then,

> ". . . dip into the future
> Far as human eye can see. . . ."

which, after all, may not be very far, and try to discern the broad movements which are affecting and will continue to affect the engineering profession. In this admittedly difficult endeavor, it would be futile to concern ourselves with details. The broader the trend, the greater its significance; and the more worthy of our careful study.

Following this plan, then, I think we can single out two great movements which characterize the American scene today, and consider their impact on the engineering profession. We shall do this with the full realization that such reconnaissance mapping leaves much detailed contouring to be done. We may be reasonably sure, however, that within the limits of error which we set up for ourselves, we can map the major features of the territory correctly.

The first of these major features is the trend toward a larger and larger element of science in industry, and hence in engineering; and the second relates to the human and social factors in industry. The one deals with the laws of nature, the other with the individual and society. They are thus at opposite poles of the engineer's world, yet before we conclude we may find a significant element in common between them.

Science in Engineering

The growing importance of science and mathematics in engineering is by no means a new idea. For at least a generation that unfortunate character the "handbook engineer," has been the laughing-stock of the profession. As a

student he wanted a "practical" education, and dodged mathematics, physics, and chemistry as much as he could. As a practicing engineer he is lost without his well-worn handbook, because he does not know any fundamental principles. Confront him with a problem not in the handbook, and he's helpless.

There is little room for such "engineers" in the newer, more highly scientific fields of engineering like electronics, physical metallurgy, and aeronautics, in which science and engineering are close partners. In the aircraft industry, for example, side by side with the growth of applied aeronautical engineering, investigations of a more fundamental nature have been necessary in the dynamics of fluids, in surface effects, in airfoil sections, and in the principles of structural design. In this relatively young branch of engineering, basic and applied science are constantly working hand in hand. The same is true to a varying degree throughout the profession, but especially in those industries which are marked by high rates of obsolescence and innovation. A general rule might be stated thus: the closer the cooperation between science and engineering, the more rapidly will the industry advance.

This close connection is not, however, to be thought of as a one-way street in which all the original work is done by the basic scientist and the engineer merely borrows these fundamental discoveries and turns them into gadgets. There is, to be sure, a certain element of truth in this view, as exemplified by a remark that Kettering credits to the Nobel prize winner in physics, Harold C. Urey. When asked what is the difference between science and engineering, Dr. Urey is supposed to have replied, "About twenty years." The implication is that after the scientists have discovered or created all the necessary basic elements of a new device or industry, engineers spend a few years cobbling them together into a useful and salable device, using no more ingenuity than is necessary to develop a workable manufacturing process. It is true that the useful application of science is the province of the engineer, that through the engineer's efforts the laboratory curiosity of today becomes the tool of industry tomorrow; but in fast-moving technological industry, the engineer is much more than a mere borrower from science. The true relationship of the engineer and the scientist may be described as a cross-fertilization of ideas, each profession contributing something which assists the other to take the next step in its own field.

Nowhere is this teamwork of basic and applied science more conspicuous than in the rapidly growing field of industrial research. The leaders of our great technological industries are well aware of their dependence on both basic and applied science, and in their laboratories they support both kinds of research. Here scientists rub shoulders with engineers, they work together on the same projects, and thus reduce or eliminate the traditional gap between theory and practice. The familiar terms "industrial chemist," "engineering physicist," and "industrial physicist" highlight the importance of basic science as a factor in engineering and industry.

In the interval between the First and Second World Wars, applied research experienced a ten-fold expansion, involving an outlay in 1941, of some $300,000,000. During the late war, as might be expected, the figure went up to the neighborhood of a billion dollars

a year, which put research in the category of a major industry. Surveys of future trends in research indicate a tremendous demand for research services on the part of industry, which may offset most or all of the expected shrinkage in research expenditures by the Government. It is clear that the growing emphasis on basic science in the training of engineers is a step in the right direction.

Though I have emphasized engineers in research, it would be wrong to assume that they are the only ones who profit by a thorough scientific foundation. Many an engineer whose life is spent in production or distribution finds himself in constant touch with science and research; and this promises to be even more usual in the future. The sales engineer, the design engineer, the factory manager, the general manager, all have a heavy stake in the success of the research department, and hence should know and appreciate the scientific basis of research. The headlong growth of technology, its increasing complexity, can mean only one thing for tomorrow's engineers—a demand for engineers trained with a strong flavor of science, combined, of course, with the practicality which is the engineer's own mark.

The Human Element in Engineering

We now come to the second of the great trends affecting industry and engineering—those human elements which are so unlike the emphasis on science which we have been discussing. The engineer has always been concerned with certain matters of human welfare, specifically those involving technology. Many examples could be cited—industrial health and safety, the productivity of labor, traffic engineering, noise abatement, the control of air and stream pollution, the modernization of building codes, the treatment and disposal of industrial wastes, city and regional planning—all these and many more are problems of human welfare in which the engineer is vitally concerned.

If I foresee with reasonable accuracy the long-time trend of our American social philosophy, the engineer will be increasingly concerned with such human problems. This will be especially true of the engineer who enters management. Since management is the goal of a large number of engineers, it is reasonable to say that the engineer's training, either in college or later, should put him in touch with the great social problems which are the concern of management. Three groups of these management problems will serve to illustrate the point. There is the group known as industrial relations—the relation of industry to its own personnel. In this field the manager-engineer is concerned with wage scales and the methods of computing wages; with working hours; with pension systems; with employee insurance; with collective bargaining; and with the intangibles that can make or break the cordiality of relations between workers and management.

In the second group are the problems of public relations, which deal with the attitude of industry toward the public at large and, conversely, of the public toward the industry. Publicity and advertising are always included here, and sales promotion may be; but in its broader aspects, public relations goes far beyond these. Its purpose is to bring the industry into harmony with public opinion, which is the only sound basis for long-range success.

The third of these categories of man-

agement responsibilities is the over-all concern which management must have toward the present and future of the social environment in which the industry exists. The manager-engineer must, for example, have an eye for changing markets, and for the psychology of buyers and users of his product or service. He must take the long view of raw material supply; he must foresee changes in the thinking of investors and of labor. He must have a feeling for the evolution of governmental philosophy, which is reflected in industrial legislation of all kinds, including taxes.

In the more technological branches of industry, all these social problems take on engineering aspects which can be solved by management only with the aid of engineers. This is one of the reasons why so many engineers have been drawn into general managerial positions, and it is the reason why every engineer who aspires to managerial rank should study these social problems.

As a matter of fact, the employment of engineers as general managers is under fire today in some quarters, because so many otherwise excellent men lack, or are believed to lack, an interest in and training for the solution of human problems in industry. It was Pendleton Dudley, President of the National Association of Public Relations Counsel, who recently pointed out that our great industries, in the last half or three-quarters of a century, have repeatedly changed their type of management to meet the most pressing need of the time. In the trust-busting era, many lawyers rose to the presidency of big companies. In the periods following financial over-expansion, bankers have gained control. In times of rapid technological progress, engineers have dominated. Today, Dudley sees the dawn of an era of social change, in which the adjustment of corporate policy to new social philosophies, as well as the interpretation of industry to every social group, will take precedence over all other problems of management. He therefore expects the responsibility for general management to be transferred to men skilled in public relations. Certainly it is possible that some leading public relations experts—and I am not talking about press agents, promoters, or advertising men—may be better prepared to establish corporate policies in harmony with public opinion and current social philosophy than most other groups, including engineers.

Dudley may be right about the coming dominance of social problems in industry, but I am convinced that technology will also continue to be a factor of vital importance to management. It follows, then, that the ideal manager for many a company will be the man who is competent both in engineering and in human relations. The conclusion, with respect to the training of tomorrow's engineers, is obvious.

Education and the Practicing Engineer

We are now in a position to summarize the nature of the problem which faces the engineering profession. We have reviewed two major trends affecting the profession—the increasing emphasis on science, as evidenced by the growth of highly technological industry and the spread of research; and the increasing complexity of, and emphasis on, the social and human aspects of industry. To equip engineers to meet these broadening demands is quite obviously a problem in training—a problem in education. And it is largely nontechnical education; it is education

for competence beyond the daily problems of technology.

If education of this kind is to be successful on a large scale, it will require the interest and active support of practicing engineers. The profession is democratically governed, by which I mean that no major program will prosper unless the majority of active engineers believe in it. Education, especially in the learned profession such as engineering, is inherently the responsibility of every practitioner. It was not the medical schools alone which lifted medicine and surgery from the barber shop level to their present eminence; this great advance, mostly in the last half century or so, would have been impossible without the support and prestige of organized medicine which initiated and still maintains a strong control over the education of doctors. It is not suggested that the engineering profession should follow blindly the methods of the medical group with respect to education, but medicine is cited to illustrate the principle that professional education, at its best, is not the responsibility of a few academicians alone, but of the whole profession. As every engineer knows who has kept in close touch with engineering schools, our educational leaders will welcome organized cooperation from the profession as a whole.

What can the practitioners of engineering do to aid in the education of engineers? First of all it is clearly a job for organized groups; only rarely can the individual working alone serve his profession as effectively as he can through his professional societies.

The idea that engineering societies can contribute to education and professional development will be recognized immediately for its complete lack of originality. These objectives are probably written into the articles of incorporation or the constitution of every engineering society in the country. But in most cases, the education thus offered has consisted chiefly of technical papers, which, though obviously important, have little to do with the needs we have been discussing. But a few professional engineering bodies have made the broadest development of engineers their business. One of these is the American Society for Engineering Education, whose membership includes, among others, most teachers of engineering. Another is the National Society of Professional Engineers, with affiliated state associations which act as regional operating units, after the pattern of the American Medical Association. A third is the Engineers' Council for Professional Development. Others, operating usually on a local or regional basis, have also done excellent work in their own territory. There is, therefore, no lack of organizations to which we may turn for action.

A Suggested Program

But precisely what action is needed? In general terms, it seems clear that three types of education, supplementary to those commonly in use, would be of great value to the engineer, and through him to society.

First, we should provide additional means whereby the engineer, throughout his career, can keep up with changing technology and science. Technical books and journals are, of course, available; but there is a real need for organized programs of study under a competent leader—programs designed for the practicing engineer.

Second, we should provide a similar opportunity in nontechnical fields. We should help the practicing engineer to acquire the breadth of background, outside of his immediate profession, which

will enable him to meet with wisdom and understanding the human problems that will confront him as his responsibilities grow.

Third, we should bring engineering home to the public, and particularly to high school seniors, in an interpretive and not a promotional spirit, so that the profession may attract only the ablest recruits.

In order to implement such a program, it seems to me that local and regional engineering societies, or groups of societies federated together, might consider the establishment, as one of their most important subdivisions, of a committee or commission on professional development composed of men who have demonstrated the deepest concern for the profession as a whole and its growth and integrity. Such a commission might include representative young men as well as men of greater maturity; it might cover all major branches of engineering; and might include a reasonable number of engineering educators and research men. The rest of the personnel might be made of practicing engineers—consultants, engineering designers, engineering salesmen, production men, construction men, managers.

It should be the duty of such a group to work out and operate long-range plans for the development of the profession of engineering as a whole, within its territory.

The actual work of such a commission, other than its general planning, presumably would fall upon subcommittees. One subcommittee might be devoted to continued scientific and technical education of engineers after graduation. In cooperation with engineering schools within its territory, its job would be to provide suitable educational opportunities, including "refresher courses" and up-to-the-minute instruction in new theory and practice, for men who have finished their formal schooling. In large industrial centers this might be done through evening classes, and in more scattered localities, through correspondence courses.

A second subcommittee might be devoted to nontechnical education of engineers. Its objective would be to provide the engineer, probably a few years after graduation, with the latest and best information on the human and social side of industry, as well as on the needs of the individual in dealing with his fellow men. Instruction would include such matters as corporation finance, organization of industrial research, patent law, psychology, labor relations, and broader aspects of economic and social philosophy.

The courses thus made available by these two subcommittees would not be offered at random, but would be carefully graded and timed to the three stages of progress of the young engineer—by which I mean:

First—the *technological* stage, when he is still a private in the ranks, taking but not giving orders. Here he needs to know, in addition to his technology, how to get along with his associates.

Second—the *supervisory* stage, when he has a few or many people working under him. At this period he needs to know much about the philosophy of handling men, and the law and public opinion about the relations of employer and employed.

And third—the *policy* stage, when he sits at or near the top, and is looked to for sound judgment and foresight in framing company policy to solve all the puzzles that confront his company in this fast-moving world.

A word of caution: No such educational program should be undertaken with the idea of producing mature engi-

neering executives in ten easy lessons. Engineers are well aware that these skills—at all three stages—can be tempered only in the heat and cold of experience. But the basic data, the organized study of what has been learned from past experience—these are certainly the job of education, and chiefly of postcollegiate, on-the-job education, where formal instruction can be so effectively tested against current experience. The purpose of this proposal, therefore, is to provide machinery whereby formal instruction not available in a four- or five-year engineering course may be made available to engineers at the time in their careers when it will be most useful to them.

A third subcommittee could be charged with responsibility for vocational counseling of high school seniors. It would organize and train counseling teams to reach every high school in its area, so far as that would be possible. It would approach its task not as a selling job, but rather with a view to helping boys to find their proper place in society. Its counseling teams would be armed with the excellent manual prepared by ECPD, and with such books as "Building an Engineering Career" by C. C. Williams. They would emphasize the rigorously high standards which the profession maintains, and they would encourage to join this select profession, only those few high school seniors whose mental capacity, personality traits, and inclinations are in accord with the demands of the highest standards of engineering. This subcommittee, over a period of years, would have the satisfaction of helping to improve the calibre of the young men entering the profession. From personal experience I can testify to the satisfactions thus gained.

Other subcommittees could be organized as the need arose, such as one on standards of professional ethics, or one on public relations of the profession.

It will be seen that this program would benefit greatly by close cooperation with the Engineers' Council for Professional Development, which is organized along closely similar lines. The ECPD has already assisted a number of local groups in forming such committees and I understand is ready to do so on request for any other group. The idea of organizing evening courses and correspondence courses through engineering societies, likewise, is not original with the speaker. It has been done in a number of places, usually on a small scale and designed to satisfy the demand for specific courses, rather than as part of a long-range plan of professional development. John S. Crout of Battelle Memorial Institute has recently suggested a very complete, well-organized plan of the latter kind, in a paper which was presented in March before the AIME in New York. I am especially indebted to him for permission to borrow a part of his plan for inclusion in the present paper.

I see, then, in the years ahead, *no less* need for practical technological training, but in addition to that, a need on the part of engineers for more understanding of science and its methods, closer coordination between research and the other engineering occupations; and especially, I see a need for engineers trained to handle their social responsibilities with skill and statesmanship. I see a need for doing a much better job of interpreting the profession to laymen, chiefly for the purpose of attracting the very finest talent into engineering. And I look to the organized profession to work hand in hand with engineering schools, to provide tomorrow's engineers with the skills to solve tomorrow's problems.

The Mathematical Engineer or the Industrial Mathematician*

By KAJ L. NIELSEN

U. S. Naval Ordnance Plant, Indianapolis, Indiana

1. *Introduction.* It is the purpose of this paper to present a portrait of an individual who must have a high place in our present day design, development, and research engineering. Whether we call this individual a mathematical engineer or an industrial mathematician is quite immaterial. Being a mathematician I prefer to call him a mathematician. Other mathematicians may prefer to call him an engineer or consent to the term "applied mathematician." However, I wish to make a distinction between the mathematician who in his academic university career does research in the so-called field of applied mathematics and the mathematician who seeks a career with an industrial organization; it is of the latter that I wish to speak.

Perhaps it would be best to make a specific definition. I do not propose that this is an all inclusive definition nor even that it is a good one, but it will serve as a basis for argument.

The mathematical engineer or the industrial mathematician is an individual who has been trained in engineering and mathematics through at least a master's degree (preferably a doctorate) and who then assumes a position with an industrial organization and practices the profession for which he has been trained.

The term "industrial organization" shall be used to denote its usual meaning, and governmental agencies engaged in research and/or production, private laboratories and any other organization, company or corporation which conducts design, development, and research engineering or quantity production.

That such an individual already exists and has for some time is, I believe, quite clear to this group and therefore I do not think it worth while to give a historical background as to his evolution. Suffice it to say that the recent military conflict gave greater impetus to the importance of mathematical paper analysis in design, development, and research engineering. However, I hasten to add that the mathematical analysis of this kind was widely used prior to the war and that the war only focused its importance and extended it to wider fields. In support of that statement I refer you to T. C. Fry's article in the *American Mathematical Monthly* † where he discussed indus-

* An address delivered before the annual meeting of the American Society for Engineering Education on June 20, 1947 at Minneapolis, Minn.

The opinions expressed herein are solely those of the author and do not reflect those of the U. S. Navy Dept. in any way.

† T. C. Fry, "Industrial Mathematics," *American Mathematical Monthly*, Vol. 48, No. 6, Part II, Supplement, June–July, 1941.

trial mathematics and which is very good reading.

Having thus defined a highly skilled scientist and assuming that you will agree that he exists, I should like to proceed to a consideration of the two main topics which necessarily are associated with him; namely,

(1) the need for such an individual in our present day scheme of things, and

(2) his background and education.

2. *The Need for the Industrial Mathematician.* I believe that it is quite clear to this group that modern design, development, and research engineering has reached the place where it relies very heavily upon paper analysis before an idea is actually put into physical being. The old concept of taking an inventor's idea and immediately putting it into metal and then testing its practicability is still with us but it must be admitted that it is not as prominent as it once was and certainly is being overshadowed by the paper analysis method, especially by the larger industrial organizations. The savings of time, labor, and expense by this method have been well proved and this is probably its biggest booster. Furthermore, the very important fact that *a paper analysis leads to ideas for inventions and mechanization* cannot be overlooked. However, I hasten to add that a paper analysis does not always furnish the final answer to a design problem; that answer can at times only be achieved after the design has been built and tested; but here again we may find a need for mathematics in the form of an assessment and evaluation of the testing.

It is difficult to say what constitutes a paper analysis; it may take many shapes and forms. However, it may be characterized in the following manner:

(1) A thorough statement of the problems connected with the design or research;

(2) A transformation of the problems into the language of an analysis which can be done on a drafting board or at a desk;

(3) A large number of problems connected with a modern design dissolve themselves into the language of mathematics. These problems can then undergo a mathematical analysis, the results of which will appear in the language of mathematics;

(4) A transformation of the mathematical results into the language of engineering;

(5) Complete the engineering to the stage of blueprints;

(6) Should the finished product undergo extensive testing then there is a further step in the paper analysis; namely, the evaluation of the test.

The mathematical analysis connected with this modern method of handling design problems has reached a high level. In many cases it has reached the level which can very well be classified as research within the field of mathematics itself. It is therefore unreasonable to assume that the mathematical analysis mentioned above can be done by the usual engineering graduate. Nor is it reasonable to say that we must therefore teach more mathematics to all our engineers. As engineers and engineering professors you will agree that the engineer's curriculum is already quite full; some universities have found it necessary to adopt the five year plan. To burden him with more advanced mathematics than he is already receiving will not solve the problem. It is my firm opin-

ion that the solution lies only in further specialization; namely, to train a mathematical engineer who has an engineering background and who majors in mathematics and preferably continues to further his education to the level of a doctorate.

Does this mean that the engineers should be taught less mathematics than they already are? Since they now have a mathematician in their midst, it may seem logical that he will do the mathematics for them and they no longer will have a need for it. However, the answer to that question is an emphatic, NO! If for no other reason (and there are others *), there is still the very difficult task of arriving at a common language between the engineer and the mathematician and this is a very important problem. Each must have some understanding of the other's subject in order that this common language may be reached. This further emphasizes the need for a specialist who has had some training in both; in other words the mathematician must also have some engineering background.

To substantiate my claim that there is a need for this specialist about whom I am speaking, I can, of course, refer to the practice employed by many leading industries today. Mathematicians have been and are being hired by industrial concerns. Aircraft, electrical, communications, and chemical industries, research laboratories, governmental agencies, and plain production companies are finding a wider need for mathematicians. However, the past method of obtaining these mathematicians have not always been satisfactory and have lead to some sad and unreasonable experiences.

As was pointed out by Fry, most of the mathematicians engaged in industry were "pure" mathematicians who had turned to applied mathematics, or engineers recruited from the ranks and taught higher mathematics by industry itself or by self taught methods. This hardly seems the ideal manner in which to approach a profession. Some companies have hired pure mathematicians not really knowing what to expect from them; in turn the employees have not known how they could help the industry and the results have at times been very unsatisfactory to say the least.

The fault has not always been with the individuals hired nor with the industry which hired them. In fact the fault lies with our educational institutions who have not educated individuals to assume such positions nor have they educated industry to the proper use of such a man. The educational problem is therefore two-fold. We must educate the individual and we must educate those who find a need for his services as to his capabilities and what they may expect from him. Let us therefore turn to the education of the industrial mathematician.

3. *The Education of the Industrial Mathematician.* I do not propose to present here a complete solution to this difficult problem. I do not believe that we can at this time definitely outline an exact program for the education of an industrial mathematician. It must necessarily come as an evolution over a period of years. We are, of course, guided to some extent by the experience of some engineering schools who are already emarked upon such a training program. However, I should like

* See, for example, W. L. Ayres, "Interesting the Engineering Student," *American Mathematical Monthly*, Vol. LI, No. 4, April, 1944.

to express a few of my own personal opinions.

Let us first subclassify the industrial mathematician into the following five groups:

1. *Statisticians.*
   Quality control, assessment, probability.
2. *Electrical Mathematician.*
   Instrument design and development, communications.
3. *Mechanical Mathematician.*
   Strength of materials, vibrations, elasticity, and plasticity.
4. *Dynamical Mathematician.*
   Aerodynamics, hydrodynamics.
5. *Chemical Mathematician.*

There may be others or perhaps we can make finer divisions of fields of interest; however, the above five should suffice for this discussion. I wish to exclude the actuary statistician since his profession is well established and has been thoroughly expounded.

Keeping the discussion still in terms of generalities there are two comments that I should like to make. First, I do not believe that taking a graduate who has had his undergraduate training along the lines of pure mathematics and putting him through a graduate school of applied mathematics will develop an industrial mathematician. It will develop an applied research mathematician who can then do applied mathematical research in an academic way, but not an industrial mathematician. In other words, it is essential that the individual have some undergraduate engineering training. The second point is that we must pay some attention to the individual's personality as well as his capabilities. His personality must fit into an industrial organization. The practice of making industrial mathematicians out of mathematics professors has at times lead to serious difficulty because a person who has for some years lived the academic university life could not acclimate himself to the routine and habits of an industrial organization. At times such an individual has become in the eyes of the organization what is termed a "long hair." As a result he did not enjoy his work and it in turn did not assume its rightful importance. As to whether or not you can educate a man's personality I shall not attempt to decide; I leave that question for our educators. Certainly some screening can be done before a life and a reputation is ruined.

In the education proper it is my contention that a doctorate is preferable and in the study leading to this degree he should cover the undergraduate elementary courses in engineering and mathematics. Furthermore, the following basic fields must be covered thoroughly:

- Differential Equations;
- Numerical and Graphical Methods;
- Theory of Functions of Real and Complex Variables;
- Operational Calculus; Vector and Tensor Analysis;
- Theory of Equations and Matrices;
- Mechanics; Dynamics; and Electricity;
- Field of Specialization.

Throughout these courses emphasis must be placed on the solution of actual engineering problems wherever possible.

I am in no position to propose an actual curriculum; however, I should like to take the liberty of making a few suggestions which may aid in the preparation of curricula and their subsequent handling.

(1) *Consult industry in drawing up the curriculum.*

It is fortunate that there are men in industry today who are familiar with both the needs of industry and who have had experience with the problems of teaching college courses. These men would form excellent consultants for the university in the preparations of its curricula.

(2) *Employ men in industry as visiting lecturers.*

There are men in industry today who would welcome an invitation to spend one semester or one year as a visiting lecturer. Of course, the university must recognize that to induce a man to spend some time at a university, the stay must be made sufficiently attractive. I believe that this can be done since it is being practiced by leading medical schools in this country. To counteract any argument that his stay in the university would be too short to bear fruit allow me to point out that besides his teaching to students the university can greatly benefit from his talents in other ways; namely, he can aid in the preparation of curricula; he can participate in staff seminars where the present faculty can benefit from his experiences; and of course, he can be retained as an expert consultant. Furthermore, he would form a very personal contact between the university and a particular industry and we must agree that closer cooperation between the two is a most desirable feature.

(3) *Close consultation between the engineering department and the mathematics department.*

Although this point should be very obvious I regret to say that in my experience I have not always found this to be true. Certainly all departments can benefit by making proper use of each other and such cooperation must exist for the greater success of *any* program.

(4) *Permit the present staff members to obtain some industrial experience.*

I believe that this is already practiced by many engineering departments; however, that cannot be said of the mathematics departments. A few—perhaps too few—industrial concerns and governmental agencies have tried (and found it to be successful) to hire faculty staff members in a temporary capacity for a short period of time, usually during the summer months when normally the universities are not running a full schedule. The benefits derived from such a relationship are numerous to everyone concerned. For a more detailed account of this theory I should like to call your attention to a paper published in the *American Mathematical Monthly.**

However, we are here faced with two problems, (a) to sell more industries the idea and (b) to sell the universities the idea of granting leave if necessary for such experience, to encourage participation by its staff members, and to recognize its worth by appropriate promotions and raises in salary. Certainly, such experience adds also to the prestige of the university in the same sense that publications do.

(5) *Encourage staff members to attend applied mathematics schools, conferences and meetings.*

Leave of absence should be granted if necessary. The university should make every effort to obtain grants, fellowships, travel money, or other university aids to enable younger staff

* K. L. Nielsen, "Industrial Experience for Mathematics Professors," *American Mathematical Monthly*, Vol. LIV, No. 2, February, 1947.

members to take active part, and active participation should receive appropriate rewards.

(6) *Educate the engineers to the existence of this specialist.*

In all probability when this individual joins an industrial concern he will be associated with the engineering department and will be placed under the supervision of an engineer. Therefore, in order that a mathematical engineer or industrial mathematician may best serve the industrial organization, these engineers must recognize the proper manner in which he should be handled. The engineers must understand his capabilities, must not expect the impossible from him and must be able to recognize the worth of his work and understand his language. This man is a highly skilled scientist; he is not necessarily a design engineer. He can help the engineer in solving his research problems, but it can be done only with cooperation and understanding. Perhaps this education of the engineer should start with a more comprehensive appreciation of mathematics on the part of engineering professors.

4. *Conclusion.* As a concluding remark I should like to say that it is my fond hope that we may educate this scientist to the extent that he may take his rightful place in this modern technological world; that as engineers you will understand him and his place among you. It certainly behooves us as educators to train any and all kinds of scientists in order that we may benefit from their endeavors both as a society and a nation; and if the need be, that they may be ready to help us preserve our way of life should it ever be challenged.

Research Policies at M.I.T.

By JAMES R. KILLIAN, JR.
Massachusetts Institute of Technology

Since the war, the relationship of research to education has been under active and sometimes vehement discussion at my institution. I therefore welcome the opportunity of outlining our present policy and of removing from behind the ivory curtain certain vexing problems that we share with many institutions. The continuance of sponsored, *i.e.*, contract, research after the war has required new policies, some of which are still *subjudice*. Moreover, the large scale of much of this research has raised questions which can be summarized in terms of an old paradox, "Have we educationally bitten off more than we can chew or are we chewing more than we can bite off?"

Educational Uses of Research

Let me begin by discussing some current problems of integrating research with engineering education, deferring until later the special problems of contract research.

We all recall the "long hairs vs. hairy ears" argument that followed the war, and the repeated assertion that men trained in science, especially in physics, proved to be more effective at applied research than did the engineers. I feel that this assertion, if analyzed, can be shown to be a half truth. Nevertheless, the half truth that remains should force and is forcing a reexamination of some of our methods and procedures in engineering education, and of our use of research as a method of teaching.

The scientists ascribe their success in handling applied research during the war to several factors: The first is that they had advanced training and most of them held doctor's degrees. The second is that they had a fundamental training in science that was both broad and deep, with the result that they were able to bring to bear upon practical problems a wider range of scientific learning and a more flexible method of thinking. The third is that the training which they had received and the environment in which they had worked promoted creative thinking of a quite untrammeled kind. They were not normally concerned by any practical or economic limitations and they were instinctively inclined to dream and speculate, with a bold indifference to limitations.

Now this kind of training and this point of view are not a monopoly of the scientist, and there are fields of engineering which have embraced them for many years. The fact remains that engineering, while retaining its capacity to work under practical limitations, must at the same time adopt more of the analytical tools of pure science and its willingness to question standard practice. The feeling is widespread in many institutions that research must be used throughout our engineering training to attract men of imaginative

minds and to train engineers who have the temerity and capacity to dream and speculate beyond the boundaries of the immediately practical.

The engineering departments at most engineering institutions have long been wedded to the principle that research and the research atmosphere are essential to the training of both undergraduates and postgraduates and that a balanced staff must involve creative competence as well as teaching competence. I believe that this tendency to deepen engineering education through stressing fundamental research is one of the most important changes now in process. I believe, too, that while engineers must always maintain their firm hold on the economic and applied aspects of their art, they can enormously benefit by promoting within their ranks an increasing number of scholars with the courage to ignore conventional conceptions and with a comprehensive understanding of physical laws and analytical methods.

The Problem of Hardware

Our concept of what constitutes effective research in an engineering department is subject to another consideration. The scientist generally undertakes to investigate a phenomenon or to seek a principle or to collect data bearing on a hypothesis. Sometimes he may be interested in working on some component of a system, but rarely is he interested in a system. Engineers, of course, do this kind of research, too, but frequently they do another kind that results in some instrument or machine or process or an entire system. In the current jargon, the scientist is not interested in producing "hardware"; the engineer frequently and properly is. Is there a real danger that too much emphasis on hardware may reduce the effectiveness of engineering research in an educational institution?

We have been trying to clarify our own thinking as to when hardware, or the design of some entire engineering system, does provide a justifiable research objective. While realizing that there is no clear answer, we have concluded that if the hardware involves some new art and there is a great demand for men adequately trained in this art, then this kind of research can be vital. I cite as an example the field of control (including servomechanisms), an engineering art that is still under intensive development. Research in this field not only must look toward the production of an instrument as the end result but must comprehend an entire system, since the assembly and balance of the system is one of the essential research problems. There is a great need for men who are trained in the art of developing dynamic control systems, and consequently any laboratory activity must deal with the over-all system.

This emphasis on system research in the control field justifies another type of research which might commonly be out of place in an engineering institution. I speak of research which involves the production of equipment. In this and a few other fields, because of the importance of the systems aspect, the production of equipment involves a new art and a research technique which is essential in training men in the field at an advanced level. There is no other way for these men to become effectively trained other than to work on a project which involves the production of control units. More importantly a systems project or the engineering of a piece of equipment can be an extraordinarily effective educational

vehicle by requiring a synthesis of all that the student has learned.

We believe that research on hardware or systems should meet these tests of educational validity. We also believe that contract research should be subject to the same tests and should not overemphasize hardware.

The Organization of Academic Research

Another problem that has required much attention is the management and organization of research, especially that kind of research which is carried on by large groups of investigators. The war demonstrated the effectiveness of research teams, and we are now experimenting to determine how effective group research can be within an academic organization. In making this experiment, we are certain that research teams should never displace the brilliant individualist who works alone, but we want to find out how the two approaches supplement each other.

One of the devices which we are using to handle group research—and to stimulate individual work—is what we call "centers of research." These are interdepartmental organizations which coordinate the activities of various departments in important fields of overlapping interest. While we call them "centers of research" because research is their predominant role, they are nevertheless playing a very important part in our educational program, especially by providing superior opportunities for senior and graduate student thesis work.

These centers of research appear to be a highly satisfactory answer to a problem which has long confronted educational institutions, namely, that of handling those interests which reach outside the traditional departmental boundary lines and require the cooperation of the specialists from several disciplines. Certain institutions have tried to meet this problem by setting up special institutes. Others have set up new departments. It is our feeling that both of these solutions seem to be lacking in two desiderata: namely, the mobilizing of the interested personnel of the various departments into a cooperative whole while still recognizing each department's special interest in the various aspects of the program, and, most importantly, the full coordination of the research with the educational program.

We have established these centers of research in about half a dozen fields, but the first and the most highly developed of our programs is our Research Laboratory of Electronics, which is operated jointly by the Department of Physics and the Department of Electrical Engineering. Some sixty-five graduate students are now doing their theses in this laboratory. It has a highly productive program of research that is managed by professors from the two collaborating departments and it maintains a concentration of equipment which is available to the staffs of the two departments.

We believe that this laboratory is serving as a pilot plant for a new type of internal collaboration among departments having the fundamental scientific point of view and departments having the applied point of view. Through such mechanisms as this we hope to effect a fruitful cross-fertilization and thus minimize any invidious distinction between the engineer and the scientist. Joint laboratories of this kind also provide a means whereby the educational staff can cope with large-scale sponsored research. These laboratories provide a staff of administra-

tive officers and services which free the educational staff from routine work, thus permitting them to concentrate on their educational and research activities.

Contract Research—Its Values and Limitations

Coming now to some of the special problems of sponsored, or contract, research, I should like to state several guiding principles which we have laid down, and describe some inherent difficulties.

Our first guiding principle is that sponsored research should be closely related to the normal program and recognized objectives of the institution. It should involve only work which can be carried out with enthusiasm by the staff and it specifically should not be work which the staff would undertake with reluctance and which would be unrelated to their educational and professional programs. A member of our staff is never "assigned" to contract research.

Our second guiding principle is that imposition of restrictions on publication of research results, either for secrecy or patent reasons, can become incompatible with the basic concept of an educational institution as a source and distributor of knowledge. Research contracts involving such restrictions, especially long-term or permanent restrictions, should be undertaken only for exceptional or emergency reasons. No arrangement is permitted which could inhibit free and effective work by the institution in any scholarly field. No project is normally accepted unless it is open to qualified students.

Our third guiding principle is that the compensation and privileges available to the academic staff, including graduate students who are members of the staff, must never suffer in comparison with the compensation available to staff engaged solely for contract research. This policy is of the greatest importance, since funds available for contract research frequently are less restricted than funds available for the regular academic program, and there is a consequent temptation to pay higher salaries to the personnel working on these projects.

We have carried out this policy of protecting the academic staff by distinguishing sharply between our academic staff, with its educational function, and the nonacademic staff employed specifically for contract research. The academic staff has important privileges, such as tenure, membership in the pension association, opportunity for graduate study, time for outside consulting, and extended vacations. None of these privileges is available to the nonacademic staff.

The compensation for nonacademic staff, however, is usually somewhat higher than are salaries of comparable academic appointees. In securing staff for research projects, we have had to meet industrial competition in recruiting, and their status with us is quite comparable to what it would be in industry.

The same general policy applies to graduate students who have part-time staff positions. The nonacademic staff member who wants to take graduate work is limited to one subject per term and he may not present a thesis based upon sponsored research work for which he has received compensation at a higher rate than that available to the academic appointee. In contrast, the regular graduate student who also has an academic appointment as teaching fellow or research assistant receives a lower rate of pay but has full graduate

student privileges, including the opportunity to work on sponsored research and use this work for thesis credit, provided of course it has been approved and properly supervised.

Maintenance of these two rates of compensation requires some dextrous tightrope walking, and is a difficult administrative procedure. In practice, our Division of Industrial Cooperation, which manages our sponsored research, gives preference to the academic staff when it is recruiting personnel for a contract project, but if the project cannot be staffed from our academic group, appointments from outside the institution are made in accordance with the policy I have outlined above. Even though the salary scale may be somewhat lower for the academic staff, the academic appointment with the privileges it carries remains a more desirable appointment.

Related to this general policy is our limitation on supplementary compensation to academic staff members who work on contract research. Here we follow the policy that teaching and other normal academic duties must not be made less attractive than working on contract research. We share fully in the following recommendations of the Committee on Academic Tenure, Professional Service and Responsibility of the Engineering College Administrative Council:

"If equity demands that supplementary compensation should be paid for extra work within an institution, the amount of such additional compensation should not be so high that it tends to reduce the importance of the staff member's regular work and salary, and to place a value on contract research or nonacademic assignment that is high in relation to the value placed on the usual academic duties.

"Care must likewise be exercised to avoid compensation inequities within an institution which result when some staff members, whose field of work may attract outside research, receive large supplementary salary payments while other staff members, in fields of less immediate application, but possessing equal or greater scholarship and professional standing, receive from the institution only their regular salaries. No plan of supplementary compensation should put teaching in an inferior position or tend to divert staff members from their obligations to their students."

In practice, our staff members working on sponsored research have enough time released from academic duties to undertake the research. Out of approximately two hundred academic staff members working part time on sponsored research, less than twenty are receiving supplementary compensation. Those who receive this extra compensation agree, for the period they receive it, to forego their privilege of engaging in outside consulting.

Other Sponsored Research Policies

Other more detailed tests which we apply to sponsored research include the following:

(a) Some department or group of departments (or an academic organization such as the Research Laboratory of Electronics) must be willing to accept responsibility for the project and must have available senior staff members who are free and willing to oversee the project. Contract research is thus under the jurisdiction of the academic departments.

(b) It must be possible to staff the project in accordance with the institution's prevailing personnel policies.

(c) It must be possible to staff the project without handicapping our edu-

cational program either by overloading the staff or by diverting from the educational program the proper amount of attention and interest.

(d) Final approval of the project rests with the academic dean who has jurisdiction. If the project is border line and the dean has doubts whether it meets the tests and principles laid down, he will bring it before an administrative committee composed of the president, the vice president, the dean of engineering, the dean of science, and the director of the Division of Industrial Cooperation.

Reduced to a single statement, these principles say in effect that the consideration, acceptance, and priority of any sponsored research project are governed by the extent to which the proposed activity will carry forward the educational objectives of the institution.

In conclusion I would reiterate that research, aimed at advancement of knowledge or development of its practical applications, is both a method of advancing knowledge and a method of teaching and that it must be both when carried on in collaboration with students. In meeting this educational test, our research programs must also help to create that subtle kind of environment where scholarship and creative activity flourish and great minds feel at home. The creation of this kind of environment is one of the major tasks of our engineering institutions.

Contributions of Science and Technology to Education

By N W. DOUGHERTY

Dean of Engineering, The University of Tennessee

This is my text:

"And he gave it as his opinion, that whoever could make two ears of corn or two blades of grass, to grow upon the spot where one grew before, would deserve better of mankind and do more essential service to his country, than the whole race of politicians put together."

("Gulliver's Travels"—Swift)

A few days ago there was an editorial in one of the Knoxville papers opposing the establishment of a Federal Science Foundation. For more than three years all of the national organizations, of which I am a member, have been working strenuously for such a measure. This difference of opinion is caused by a difference in understanding of what is meant by science, its development and its implications. Today I wish to talk a little about the contributions of science to education and in so doing I will trace briefly the movement toward originality and the questioning attitude.

Here in Memphis you make a special effort to cause a newcomer to feel at home. Should you find his basic philosophy out of tune with that generally accepted in your town you will, like citizens of all other communities, question his motives and resist his innovations. Leaders in education are the same leaders that we find in other activities. If innovation upsets their beliefs they resist and move into place their heaviest artillery.

Before developing the contributions of science and technology I will give a brief review of the battle between utility and non-utility. Sometimes I believe that Don Quixote has returned and is doing battle with his wind mills all over again.

The Beginning of Formal Education

The life of Lycurgus gives us a picture of education in early Sparta. It was strenuous and designed to fit the youth to take their places as men when they reached the age of citizenship. No doubt much of the training was not necessary for the purpose but the over-all product succeeded in carrying on the traditions of a sturdy people. Utility was the watchword of all their education.

During the period of Athenian greatness again we had a regimen of training for citizenship but this time on a broader base than the training of Sparta. Plato enunciated the doctrine of "Philosopher Kings," or educated rulers of the state. He recommended that the wisest men be placed in charge of public affairs and then only after they had shown real aptitude for government. This is what we do in busi-

ness in America but too often we take the attitude that anyone, who can be elected by the people, can govern well. Our experience has shown that aptitude for government is as essential as free public choice.

When the European universities were founded they adopted curricula that were useful. Objectives were stated and programs developed to approach the stated objectives. Of course, always the curricula included known knowledge or known information. Whatever custom has dictated habit will continue until a crowding of the program will squeeze the old courses out. Throughout the Middle Ages the program was made up of the humanities, language, literature, speech, history, philosophy, architecture, music, the fine arts and mathematics. Since the books were written in Latin and Greek knowledge of these languages became the hallmarks of the scholar.

Probably the strangest thing in all education is the veneration with which the Ancient Languages have been held and the persistence of the oldsters that these languages have unusual educational value. True, the reason for their study has passed with the translations but the study itself persists as a mental discipline or as an aid to the learning of English. I don't object to anyone learning Latin and Greek who wishes to learn ancient languages but I do object to the notion that these languages are necessarily badges of educated people.

When once an idea or method is accepted it persists until uprooted by a substitute idea or method. Often the battle is long and the change comes many generations afterward. This persistence of the old poses a whole series of problems in modern education. New subject matter has been developed, new skills have been acquired and new methods have been devised. These have been superimposed upon the old way of doing things and as a result there has developed great differences of opinion as to the correct course to pursue. No simple answer is in the offing.

Some very distinguished educators decry the study of utility subject matter; others go to the extreme of "no utility, no study." If we follow the usual law of compromise we will accept a pathway somewhere in between these extremes. The doctrine of the mean, or of the middle of the road, is very old and it usually finds a workable plan. Let me illustrate the different points of view by quotations from an apostle of each extreme.

> "But whatever the subject matter and approach, the main emphasis should always fall on understanding, or insights for their own sake, rather than on insights merely as a means of action and belief. Thus a liberal education should include the study of religion as an historical phenomenon, a type of human experience, and a pattern of belief . . . it should not demand acceptance of any specific religious beliefs or promote any specific religious practices. Its function is to enlighten, to promote understanding, not to proselytize. This applies not only to religion but to morality, art, and politics. In a democracy, it dare not even proselytize for democracy itself."
>
> ("Liberal Education Re-examined.")

Being a technologist I have always had difficulty with this point of view. It is strange that in a democracy, where one is permitted to hold these opinions, it is counted illiberal to say a good word for democracy. Our kind of religious belief will allow its followers to study all other kinds of belief, yet the follower must not say a good word for

his own religion. The study is to promote understanding and not to make converts. Now let us examine the other point of view:

"Knowledge, notwithstanding its great value to people generally, is not to be regarded as an end in education, but simply as a means to other ends which lie beyond. *It is those ends which are valuable*, rather than the knowledge, itself; and, unfortunately pupils can, and often do, acquire knowledge without attaining the ends at all."

("Permanent Learning."—W. H. Lancelot)

Here is one educator looking for knowledge for its own sake and another bothered because some students get knowledge for this purpose and not because of its utility. Down deep under the skin of both these educators we will find that they are both interested in the great task of living and, of necessity, they are interested in the coordinate task of making a living. One would emphasize the art of living, the other would emphasize the science of making a living and its implication on the living of others. Both are important; one cannot exist without the other. If we think of making a living as an integral part of the living we can begin to reconcile the two points of view.

To be a graduate of a technical school one runs the danger of overemphasis of the "doing and the getting" rather than on "the being and believing." Nearly always the doing and the getting makes possible the being and believing.

How does it come about that we are attending the commencement of a technical high school? It is a type of school which began in this country in 1824 and has grown in the 123 years to a real stature and satisfies a very pressing public need. Science as a method of thinking is very old though its growth and application is very new. Down the corridors of time men and women have applied the questioning method to their surroundings and have thus contributed to the sum total of science.

We usually think of the Prophets of Israel as religious leaders, and they were, but when they spoke against formalism, the substitution of understanding for sacrifice and the seeking of Jehovah for burnt offering they were following the spirit of freedom which is the spirit of science and technology. In the golden age of Athens there was a spirit of inquiry, a searching for the truth and at times men caught the spirit of freedom which led to originality and the breaking away from tradition which slavishly ties the human mind to accepted customs and denies to them future possibilities.

Then there settled down on the world a fog of tradition and status quo which we now call the Dark Ages. It was not broken until Columbus discovered America and men of good will began to question the authority of other men. Such sages as Galileo and Copernicus broke with the past and became the vanguard of a new method of thinking. For four hundred years men have sought out new things, new ideas, new methods until today we are beginning to understand the world about us and to postulate how it came into being, how it is maintained and how human beings can live together on it.

The change from the Dark Ages did not come in a day. It was a long hard struggle out of the night. We are at its morning tide rather than at its high noon or setting sun. As you go out into more education or into the life of the community you will take your

place in society at the beginning of a new age. You, and others of your kind of training, will have to learn how to control and manipulate this new strange world of atomic power.

No works, no achievement has fired the imagination of the American people like the activity at Oak Ridge, Tennessee. Right here in our State we have the number one research project of the World. Its possibilities stagger the imagination; its probabilities are taking very active shape both as an energy source and as a harbinger of new frontiers in medicine and biology. Its power has been demonstrated. When I saw the picture of a column of water 2,000 feet in diameter raised to a height of half a mile I was convinced that we had a power source which would compare with Vesuvius at its heyday. All we have to do is to develop its control and economical use, but power is probably not its greatest possibility. Radio-active isotopes may be used to study the life process, to find cures for dreaded maladies, and to prevent the recurrence of disease.

The effect on our way of living may be illustrated by a brief review of things we already know. In 1763 Watt began his work on the steam engine. The device was old at that time but it had not been improved to a desirable state of efficiency. Under Watt's genius the steam engine took form as we know it today and along with its development the world has changed over from the use of manpower to the use of steam power. If we tried to enumerate all the changes which have occurred our list would be very long. Three developments will be enough to illustrate what I mean. The factory system took the work from the home to the engine operated plant; the steam locomotive took the burden from the backs of men and animals and placed it on bands of steel; and the steam boat made obsolete vessels driven by wind and placed their control in engines far below decks. Should we follow the ramifications of these three changes which were due to the steam engine we would find that the path was strewn with misunderstanding and fears along with improvements and great advantage.

One more application of power will help us to vision the changes that may come with this new source of energy. In the 1880's the dynamo was developed to a usable machine. Faraday had discovered it fifty years before but its development and use waited for Edison and his genius for making useful things. For belts and gears were substituted wires, switches and resistances. A generator at one place could pull motors all over an area. Motors were developed of all sizes from that operated by the dentist to that housed in the electric locomotive. The factory system became the assembly line of operation and the home became filled with electric devices and gadgets. Our homes in 1947 are far different from those of our grandfathers before the turn of the century.

Now let us take a look at an idea which has changed practically all of our methods of treating disease. Louis Pasteur proved the germ theory of disease and by this one step he made possible the treatment of hundreds of diseases that had baffled the best minds before his time. Smallpox, typhoid fever, yellow fever, malaria, dysentery, food poisoning, and a hundred of others fell before the new onslaught. The life span was increased and many of the scourges of the Dark Ages were only things of history.

Here at our very doors may be a new

agent which will combine the changes of great power with the changes which came with the germ theory of disease. Your day will be a very interesting day in which to live.

Now let me come back to the warfare between utility and non-utility in education. The battle will probably not be won by either side but by a better interpretation than either side has given to this date. Utility cannot exist by itself; it must carry with it some of the very virtues claimed by the non-utility advocates.

What are some of the additions to education which have grown out of science and technology? First of all, there has been a raising of the level of manual skills for the whole population. In Watt's day the greatest handicap he had in making an engine was the skills of his workmen. Today hundreds of workmen have skills not possessed by a single workman at that time. The schools have assumed a responsibility in furnishing many skills which were acquired by the apprentice system a couple of generations ago.

During many centuries the race has developed methods of qualitative thinking; science has added a method of quantitative thinking. True, there have been people in every generation who have dealt in figures and balance sheets but the idea of accurate measurement is comparatively new. New for more reasons than one; first, there was little need for accurate measurements, and second, there was no equipment available for such measurements. Now science always asks, when, where, how much, how little, how accurate, what error, what tolerance, etc. To the educational process has been added all kinds of ways of making measurements and methods of determining their accuracy. It is important to know the quantity, the cost, the availability and the amount of work necessary to make a machine or a product ready for use.

Probably the distinguishing characteristic of our thinking over that of the ancients is the questioning attitude. As we measure quantities and we try to measure everything, we constantly search for magnitude. If it cannot be measured we raise a question about its very existence. No longer do we take statements on authority; we want authority to establish itself and prove that it has a right to speak. Oracles, divinations and seers have a hard time making places for themselves in our generation. A thing is not necessarily good because it is old, neither is it good because it is new; it is good because it serves a useful purpose and is suited to that purpose. There are few universals anymore.

I say we are wary of universals though we may be much nearer to them than ever before. For example, all matter may be one matter and certainly matter and energy are very much akin to each other, if not identical.

The experimental method offers a way to discover the soundness of a point of view or the conclusions from observations. It does not accept on authority unless the authority is bolstered by supporting data and it furnishes a method by which the data themselves may be tested.

Many are distressed that they cannot have authority in which to seek refuge. They do not care to do the testing, they do not desire to do the questioning and consequently have little need for the method of experimentation. They can go their merry way and believe as they please but should the sailing ever become rough, and they desire to test their position, they still may use the experimental method. True it de-

mands a certain amount of aptitude for good results, but the questioning is the beginning of the method.

Science has given us a concept of the nature of the world, the universe, and all living things about us. All will agree that it is more satisfying to see nature through the eyes of understanding than through the eyes of superstition and fable. The better the understanding the more able we are to find our place in this vast creation. The more we know about ourselves and our methods of thinking and the actions of our emotions the better will we be able to live with each other. Science has made long strides to such an understanding; more science will carry us farther in the way.

We have learned that efficiency in service means symmetry in lines and harmony of the parts. Here is a law which makes possible the production of a piece of art by the designer of a streamliner, the airplane or the skyscraper. Yes, we could name a dozen other contributions to esthetic construction and not exhaust the catalogue. Let us consider for a moment the automobile engine. It works under a hood, it is to be seen when being serviced or dismounted for repair, yet its lines are symmetrical, its form is not homely, and withal it is a thing of pleasing appearance. Its design is for efficiency and performance and not for beauty or appearance. Were I an orator or a painter I could make a good word picture or a canvas which will give you the idea that I am trying to express. As the scientist or technologist does his work well he creates machines, structures, and devices which may be contributions to art as well as contributions to his major objective of construction and production.

Finally let me emphasize utility in production and distribution as a part of the larger program of resource conservation. Wanton waste borders upon the criminal; careful use for real needs is a very high virtue. As any worker does his job well he is contributing to the general welfare of the community and state; he is conserving resources for his and future generations. Any instruction which emphasizes this phase of production and consumption is making a contribution to the general welfare of the state. We should commend such a program rather than condemn it.

Utility is a virtue when we are serving a real want; utility may be a vice when it causes us to fragment our knowledge and place small bits of it into labeled compartments without relation to the whole picture. Let us not be afraid of utility but let us shun extravagance and selfish greed which may come in the wake of utility. Efficiency is commendable; it will produce goods and services which will be an asset to us all.

Conclusion

Seventeen and eighteen years ago when you were being born there were those who cast aspersions upon the technologist. They said he was creating a Frankenstein monster which might turn and consume or destroy our way of living. We considered turning away from machinery and we tried to make work with pick and shovel, with rake and wheelbarrow. In some places we wore the leaves out by raking them so much. Then we decided that machinery had come to stay and the *"back to the hand tools"* was a snare and a delusion. When the war came we were right glad that we had not junked our skills along with our discarding of the laws of econom-

ics. We had our debt but we still had our skills and they were enough to give us production in spite of our loose economic structure.

There is a place in our society for every kind of knowledge. Each and every one of us has a right to learn whatever is useful and lawful, and there is no good purpose served when any of us points his finger at any others of us because of the form or bent of our study. There is an equality of all knowledge which should make us glad that some of us may have one kind of talents and someone else some other kind of talents that the whole scale of knowledge may prosper and grow in our midst.

Let us therefore conclude that science and technology have their place in our educational plan. They have fought for this place and they deserve it because they contribute to our thinking process, they add to our esthetic values, they help us harmonize our lives with our surroundings, they show us how we can conserve for the future, and they give us a better understanding of the qualitative thinking which is the heritage of the race. Let us, therefore, hold our heads high with a full knowledge that we will be able to contribute our fair share to the sum-total of education and that our knowledge is essential to the solution of the current problems of our day.

Judicious Programming of Structural Courses*

By ALFRED L. MILLER
Professor of Mechanics and Structures, University of Washington

Application of sound judgment and rational appraisal of all phases of our academic programs are paramount essentials at this time of increased demands on the civil engineering curriculum. Increase in humanistic-social studies within the scope of present curricula can be accomplished in one of two ways; either by reduction of technical and professional courses within the four year pattern, or by extension to five years. The latter choice, followed by several schools, is in the direction of least resistance and implies that the technical courses as now given are sufficiently satisfactory. However, since the majority has chosen to retain the conventional four-year program, reduction in quantity and, perhaps, quality appears to be inevitable. Our experience at the University of Washington suggests that problems arising from the present trend can be solved by judicious programming with the possibility of maintaining or improving both the quantity and the quality of structural courses.

Exactly twenty years ago, our curriculum in civil engineering was completely revised. At that time it was an accumulation of thirty years of miscellaneous courses haphazardly arranged, the result of pioneer growth typical of curricula in similar institutions. Each division in civil engineering was placed in a clearly defined pattern and alloted an amount of credit appropriate to its relation to the field. Twenty per cent of the upper division (junior and senior) credits were assigned to structural courses. It was decided that a continuous sequence of low credit courses was preferable to intermittent high credit courses. Twenty years of experience have proved conclusively the wisdom of that choice and, in addition, have served to reaffirm certain basic facts of learning which are substantiated by every day experience. They are not new discoveries but age-old principles which have fallen into disuse by our educational system at all levels, primary, secondary, and collegiate.

Several precepts, which are relevant to this dissertation, deserve to be mentioned. Admitting their triteness, while emphasizing their extreme importance, these simple statements provide the background of understanding for suggestions which follow.

A sequence of natural growth is the essence of any effective program of learning. The student must be aware that the program follows a clear path from his background to his objective.

Learning is attained by frequent, repetitive use. Items of major importance should be introduced as soon as possible and repeated as often as possible while

* Presented at the 55th Annual Meeting A.S.E.E. (Civil), Minneapolis, June 17–21, 1947.

those of minor importance can be placed accordingly.

Prerequisite training always falls short of expectations. Essential prerequisite material must be repeated in subsequent courses. Courses at the professional level do not completely attain their objectives and must be followed by continuous study on the part of the individual in the practice of his profession.

All progress requires change but indiscriminate change instead of producing improvement usually results in retrogression as attested by numerous examples in diverse fields including the scholastic. When changes in training for a profession are undertaken, provision must be made to remedy or neutralize errors as soon as they appear.

Engineering education is not the modern substitute for apprenticeship but is training for entrance into a profession. Minutia, trivia, and drill in techniques, should be subordinated and reserved for a term of internship in engineering employment; otherwise advancement beyond sub-professional levels will be made more difficult because of misspent academic training.

The adjectives "difficult" and "unfamiliar" are synonyms. Likewise, "easy" and "familiar" are identities. Any specified item of our special discipline is difficult only because it is unfamiliar. It is unfamiliar because of lack of proper relationship with its context.

A well-considered program embodying the aforementioned precepts is the single prime requisite for effective professional training. The diverse divisions of civil engineering have a common interest in structures. This does not mean that the structural division is the most important or that all civil engineers should be structural specialists. However, it does mean that the structural courses can provide the unifying stem of the upper division of the civil engineering curriculum. In order to serve this purpose, the stem itself must be unified.

Academic scheduling by school years and by quarter or semester terms complicates planning and increases the importance of coordination within the structural sequence. It is practically impossible to correlate sub-divisions of the sequence and the school calendar although they should be related to the greatest possible extent. At the outset, allocation of an appropriate number of credit hours throughout the third and fourth years should be the extent to which the calendar is permitted to affect the program.

Subdivision by function (bridges, buildings, dams, etc.) provides a system of classification but, being based directly on diversity, defeats the objectives of a program. Similarly, subdivision by material (wood, steel, reinforced concrete) fails to provide the pattern for exactly the same reason. Both systems are based on obvious differences and tend to accentuate these differences in spite of the best efforts to the contrary. Both plans have been tried and have fallen short of our expectations. Six separate compact compartments developed despite every effort to counteract the tendency.

The mechanics of structures is the common ingredient of our discipline, regardless of function and material. It is the obvious stem along which the information and details peculiar to special uses and particular materials can be appended. Classification by type of structure is not uncommon in both curriculum and literature but as currently used it contributes to greater diversity than subdivision either by use or by material. During the first fifteen years of our efforts toward satisfactory programming, several ten-

tative experiments suggested the feasibility of a mechanics stem. As a result, during the disturbed program of the war years with their accelerated tempo it appeared that failure of an experiment in programming would be insignificant compared to other deleterious influences over which we had no control. Also, it became immediately apparent that the prerequisite backgrounds of army and navy trainees were so diverse that direct repetition of the mechanics prerequisite was mandatory. Discarding all expectations of attaining peacetime objectives in quantity but fully maintaining our objectives of quality, structural courses were programmed on the mechanics stem.

Beginning with the roots of our discipline in the field of mechanics, a sequence of natural growth proceeding in a clear pattern from the familiar to the unfamiliar was followed. The "three problems of structures" appearing in our older literature were revived and incorporated into the pattern with favorable results. To recall, the "three problems" are:

1. Given a structure and the loads, to determine the effects expressed in stresses and deformations.
2. Given a structure and prescribed stresses and deformations, to determine the corresponding loads.
3. Given the loads and dimensions, to design a structure which is adequate and economical.

Inspection of the basic aspects of the three problems reveals that they embody in natural order the procedures of our specialty. First, interpretation of facts gained by experience and experiment provides theory and specifications. Second, the theory and specifications are verified by further experiment. Third, application of theory and specifications provides a structure to satisfy a need. Briefly, the first and second procedures are "theory" and the third is "design." Accordingly, the first year of the program is devoted to theory and the second is chiefly design.

Appraisal of all types of structures reveals the obvious fact, commonly disregarded, that a structure is an assembly of solid materials which fulfills its functions by acting as a unit. Whether it be an airframe or a retaining wall, its members are no longer discrete portions but are components of an integrated whole which inevitably participate in the action of the whole. The unity of action of the structure itself suggests the unity of treatment essential to an integrated program. The adequacy of a structure is determined by the adequacy of each member and its connections to resist rupture and excessive deformation. Thus, the key to our present program is introduced in the form of the typical structural component which is subject to the actions of loads immediately applied to it and all other actions transmitted to it through its connections.

From the conventional viewpoint, this approach to the subject is fraught with almost insurmountable difficulties. Arising from unfamiliarity with fundamental prerequisite mechanics and mathematics, they can be overcome by proper presentation of basic mechanics and mathematics at the structural level. When coordination of prerequisite courses in mechanics and mathematics is obtained, much time and misdirected effort will be saved. Lacking this coordination, the remedy is the responsibility of the

structural division. This can be done only by reintroduction of prerequisite material in a form and language consistent with the pattern which is to be developed. For example, $M = A$ Sin $kx + B$ Cos $kx + f(w)$, the equation of general flexure should be developed and applied. The need justifies the effort which will be rewarded many fold. The situation is the more difficult because mechanics has impressed the student as a heterogeneous miscellany of unrelated special cases and formulas expressed in terms of a mystical philosophy known as mathematics. This unfortunate situation exists because of failure to understand that mathematics is simply a precise, rather limited, and very useful language, instead of a philosophy which contains the secrets of the universe.

A sequence of natural growth, mentioned previously, is the most important requirement of an effective program. It must have its beginning in familiar, basic fact and follow a path of orderly development toward its objective. There is no doubt that the structural sequence originates in mechanics, particularly mechanics of materials. In that subject the two basic facts and the two fundamental hypotheses from which the whole of structural theory springs are introduced and applied in their simpler aspects. The two facts are: (1) The Principle of Equilibrium, inherent in the very nature of force, and (2) The Axiom of Superposition, the whole is the sum of the parts. The two hypotheses, by means of which observations are idealized to permit simple mathematical statements, are: (1) Navier's Hypothesis of the linear distribution of force, and (2) The Hypothesis of Elasticity, which supposes direct proportionality of force and displacement. All structural theory and the tools for its application are derived by abstraction and approximation from these four elements.

Prerequisite preparation, even though it be of superior quality, can supply the materials but cannot construct the foundation of the structural program. The foundation must be provided by the structural division. Too often, this essential requirement is not fulfilled because of our impatience to cover an extensive field in limited time. Neglect of this obligation vitiates against attainment of our objectives. Repetition of the four elements of mechanics and a summary of essential mathematics are the materials for the foundation.

Basic material should be reviewed at the structural level. Several plans have been tried. To this time, the most effective approach describes structures as massive, framed or special. A massive structure such as a gravity dam, provides the opportunity to consider force characteristics, superposition and Navier's Hypothesis. It must be remembered that the object is not to analyze a dam but to review the fundamental principles and procedures. Explanation of Navier's Hypothesis apart from elasticity, to which it is not related, is highly desirable. Special structures include suspensions, arches, thin shells, etc. and are not included in the required undergraduate sequence but are given in specialized elective courses.

Framed structures are defined as assemblies of two kinds of components: (1) Panels, including sheets, plates and slabs, and (2) Members, including beams, columns, struts, ties, etc. The panel is regarded as a special kind

of member, being relatively thin, wide, and long, which may span in two directions. Types of framed structures are:

1. Panel, composed entirely of panels joined along their edges.
2. Rigid frames, composed of members, with or without panels, integrally joined and subject to loads applied within the spans.
3. Trusses, composed of members joined in a pattern of triangles subject to loads applied at the joints.

The typical member, common to all types of structures listed above, is a practically straight portion of theoretically elastic material, usually of uniform cross-section, which is attached at its span-ends to span-ends of similar members. It participates with them in transmitting loads and resisting rupture and deformation. Consideration of an illustrative typical member provides an introductory picture of its participation as a component in the behavior of the structure as a unified whole. The typical member, in general, is subject to a complex force distribution at its span-ends which is arbitrarily simplified to the conventional four components: direct, moment, shear, and torsion. Determination of stress intensities and deflections within the span cannot be made until span-end conditions are known.

All structures are supported by the earth or some intervening structure. External attachments of structural assemblies include innumerable possibilities. For purposes of calculation the range of possibilities lies between the lower limit of the hypothetical frictionless hinge or knife-edge and the upper limit of full fixity. The single-membered structures are the cantliever, simple, supported cantliever, and fixed beams, columns, and shafts of basic mechanics of materials. All are characterized by hypothetical span-end conditions. Each is a special, idealized case of the general member.

The foregoing description is not intended as instruction for those who are familiar with the field but to suggest the picture that should be presented to the initiate. From this point, the natural next step is the study of structures of two members, the elementary truss and the elementary rigid frame. In this connection, the fundamental tools should begin to take shape. The distinction between primary and secondary effects in both stresses and deflections should be emphasized and verified by theory. This requires the introduction, probably for the first time, of the subjects of general flexure and the derived concept of elastic energy. Proficiency in the language of mathematics is required for this purpose. Time and effort devoted to the development of this proficiency is an investment if for no other reason than to reveal mathematics as a servant rather than a master. Sastifactory results cannot be obtained during the first year although they may begin to appear during the second year. Time is required to erase the imprint of years of indoctrination.

At this point natural division of the sequence will appear: (1) the mechanics of the structure and (2) the mechanics of the member. The former is unrelated to the material and includes reinforced concrete, steel, and wood without distinction. The latter is specifically characterized by the material. Also, the structure must be analyzed before its members can be

studied. Unfortunately, when this order is reversed and structural members and connections are considered without regard to the behavior of the entire assembly, effectiveness of the program is enormously reduced. Mechanics of structures and mechanics of materials can proceed simultaneously; one supplements rather than interrupts the other.

After the general member is presented and the conventional single-membered structures are reviewed, two paths appear which cannot be followed simultaneously The alternatives are rigid frames and trusses. The choice is a matter of personal preference since valid reasons can be found for either. Our experience indicates that rigid frames followed by trusses offers more opportunity for correlation with mechanics of materials and consideration of loads on structures. In addition, it provides for the early introduction and subsequent repetition of the more important fundamental principles and tools. The program is planned so that all fundamentals of theory can be developed in the junior year.

The program of the senior year repeats that of the junior year in about the same order. Theory is treated by reference and repetition (not duplication). The techniques of design, application of specifications and codes, and practical aspects of construction can be given the attention which they deserve. A fairly comprehensive view of the whole of structural theory gives a background for the development of structural judgment. Simultaneous consideration of the three materials in design studies contributes much in this respect. For example, the design of a short span highway bridge in each of the three materials arouses greater interest and provides more professional training than the same time and effort applied to an imposing structure of one material. Aside from the subject, the word "assume" has been dropped from our vocabulary because there is a natural sequence in each structural design similar to that of the program itself which discredits the assumption method appearing throughout the texts as either fortunate guesses or preguessing a problem that has already been solved.

There are several practical disadvantages to the type of program just described Current textbooks are not adapted to this order of treatment and teaching by the conventional textbook method cannot be used. Several books are needed for reference in each course resulting in a small library by the end of the sequence. As a result, the student has used but a small portion of each book and is inclined to be overcritical of the book requirements and of the books themselves. A considerable amount of supplementary material is needed to simplify complex treatment by the authors and to modernize current books by making up the five to ten year lag that seems to be unavoidable. The full two year program for a given class must be fixed in advance and all instructors who participate in it must be fully cognizant of any changes that may be necessary in order to avoid omissions and duplications.

Accurate self-appraisal is both improper and impossible. Evaluation of the experiences of our graduates together with their counsel and frank criticism attests the value of judicious programming. It is very clear that

careful planning of a sequence is the most important factor for the improvement of structural training. There is nothing novel in beginning at the beginning and deliberately proceeding from the familiar to the unfamiliar along a sequence of natural growth with frequent repetition of the important principles and tools. Also, following a path into an extensive field of knowledge guided by the pattern of that sequence is not extraordinary. However, it behooves us to pause and consider our ways from time to time in order that we can better serve. Many problems of the present day can be resolved by application of time-proven principles and diligent effort.

The limited scope of this presentation leaves much to inference and implication. Emphasis of the importance of programming, the characteristics of an effective program, and suggestions to those considering program changes are its objectives. Prescription of precise details has been avoided. Description of successes and failures would fill many pages. May our efforts encourage those who strive to increase the effectiveness of professional training to the end that attainment may approach our highest aims.

Necrology

Joseph Peter Connolly, President of the South Dakota School of Mines and Technology since 1933 and associated with that institution since 1919, died October 7, 1947, after a lengthy illness.

President Connolly, a leading state figure in the field of geology and science was the author of numerous bulletins on mineralogy and the economic geology of the Black Hills and was also a contributor to the National Geographic magazine and other journals. In 1940 he served as leader of the National Geographic Society-South Dakota School of Mines joint paleontological expedition. He was a member at large of the state committee on economic development, member of the South Dakota Natural Resources Development commission, an honorary member of the executive board of the Black Hills Area Council of Boy Scouts, a member of the Lumber and Mining committee of the Rapid City Chamber of Commerce, and in 1933–34 was vice president and director of Civic Improvements Inc. Dr. Connolly had been a member of the A.S.E.E. since 1937.

Progress Report of the Committee on Undergraduate Curricula *

Purpose

The Committee on Undergraduate Curricula of the American Society for Engineering Education was appointed during the past year to study and to make recommendations to the Society regarding the requirements to be met in building undergraduate curricula and the most effective methods to be applied in educating prospective engineers.

Committee Assignments

The early activities of the Committee have been confined to a study of chemical, civil, electrical, industrial, mechanical, and metallurgical engineering curricula. As the work progresses, the Committee may recommend extension to other curricula.

Six Subcommittees, as listed below, have been formed with the membership of the original Committee:

Subcommittee on Chemical Engineering

Joseph C. Elgin (Chairman)
Robert M. Boarts
Thomas K. Sherwood

Subcommittee on Civil Engineering

Robert B. H. Begg (Chairman)
Clarence L. Eckel
Frank Kerekes

Subcommittee on Electrical Engineering

Paul Cloke (Chairman)
John H. Lampe
Joseph Weil

Subcommittee on Industrial Engineering

Ralph M. Barnes (Chairman)
David B. Porter
Ray L. Sweigert

Subcommittee on Mechanical Engineering

David L. Arm (Chairman)
Llewellyn M. K. Boelter
Harry L. Solberg

Subcommittee on Metallurgical Engineering

Robert F. Mehl (Chairman)
John Chipman
Matthew A. Hunter

Approach to the Problem

Engineering education has been beset by special difficulties, some fairly subtle. This is doubtless due in part to disagreement within the profession as to the essential qualities that should characterize an engineer. We need to determine our position so that we may progress from that point.

The first necessity is for careful planning as to education in engineering. Is is of vital importance and cannot receive too much attention from the national professional societies. For any given branch of engineering it must be decided:

* Presented at the Fifty-fifth Annual Meeting of the A.S.E.E., Minneapolis.

1. What is the scope of the branch of engineering in question;
2. What qualities—what abilities-to-do—are needed in the graduate;
3. What is the body of information that must be learned if the graduate is to render maximum service in the field;
4. How may a curriculum be assembled which will provide both the required body of information and the training necessary to develop in the student the qualities needed.

Each Subcommittee of the Committee on Undergraduate Curricula is now engaged in preparing what the members of the Subcommittee consider the ideal undergraduate curriculum for the field of engineering designated. In considering these curricula, the Subcommittees have not felt it desirable at this stage to attempt a listing of specific courses, course content, or time distribution and allocation. It is realized that such a study will take several years to complete and that as background material the general objectives of engineering curricula should first be determined. This report concerns those objectives—the qualifications, criteria, and ideals which it is felt the engineering curricula should strive to meet.

General Objectives of Engineering Curricula

In its first approach to the problem, the Committee accepted the aims and scopes of engineering curricula as prepared by the Committee on Aims and Scope of Engineering Curricula and published in the March, 1940, issue of the JOURNAL OF ENGINEERING EDUCATION, and also as stated in the May, 1944, issue of the same JOURNAL in the report of the Committee on Engineering Education After the War. The American Society for Engineering Education and the Engineers' Council for Professional Development have accepted the aims and scopes of engineering curricula presented in these two documents. To the conclusions of the two ASEE reports our Committee wishes to add two new elements of purpose:

1. To cultivate competence in dealing with human, as well as social and engineering problems; and
2. To unify in the mind of the prospective engineer the courses of his curriculum by employing in all of them the same fundamental approach to problems.

The problem of the four- versus the five-year curriculum has been discussed for many years. This Committee believes that by proper attention to the problem of undergraduate teaching the work to be done in the training of the student for the bachelor's degree not only *can* but *should* be done in four years, and that a fifth year at the undergraduate level merely subtracts a year from the student's professional life. The Committee is therefore working on the assumption that four years of training can equip the student with sufficient basic knowledge and facility in applying that knowledge to enable him to enter an internship in the engineering industries or to continue further studies. This conclusion conforms with that reached by the Committee on Aims and Scope of Engineering Curricula,[1] as follows:

"Engineering colleges serve diverse functions and prepare men for a wide range of technical, administrative, and

[1] Report of Committee on Aims and Scope of Engineering Curricula, JOURNAL OF ENGINEERING EDUCATION, Vol. XXX, No. 7 (March, 1940).

executive responsibilities. Technological education should, therefore, be kept widely available, and engineering colleges must continue to serve a correspondingly wide variety of purposes. They should not limit their aim to preparing young men for professional registration and practice.

"The present flexible arrangement of four-year undergraduate curricula followed by postgraduate work will better meet the needs served by engineering education than will longer undergraduate curricula of uniformly prescribed duration."

In preparing its report, the Committee will also consider the question of entrance requirements. There can be no doubt but that much of the difficulty in engineering education originates in the lack of articulation between pre-college and college training. What is needed is cooperative effort between the two. However, the matter is broader than that and will be taken up and discussed more fully by this Committee. Attention was drawn to the importance of selection and admission of students by the Committee on Engineering Education After the War,[2] as follows:

"Two problems stand out as of great importance: (1) Devising more valid means than have been employed in the past for selecting and admitting students and insuring better preparation in secondary schools, and (2) building up faculties not only to the pre-war level of effectiveness but well above that level. Engineering education can never advance beyond the qualifications of its students and teachers. Hence, the engineering profession, industry, and the public who have a vital interest in its welfare, should vigorously support every possible means of improving the quality of its personnel."

What factors must combine now to keep the engineering profession abreast of the other great professions and to assure the engineer his rightful place in society? By design, let us make the training of the engineering student broad; let us encourage him to make the rest of his life follow the same pattern.

The engineering graduate should be very firmly grounded in three fields:

1. *Basic science and mathematics.* The engineer must be sufficiently well trained in fundamental science to have a genuine grasp of the science involved in his work. This grasp must be good enough that he may put it to use, that he may turn instinctively to science to disentangle a problem, and that he may work with scientists cooperatively upon a problem. His familiarity with science in a general way must be great enough that he may continually be able to apply the results of old science and of new current science to his work.
2. *Engineering.* The engineer must be thoroughly grounded in engineering principles and techniques so that he may deal creatively with engineering problems. Engineering education today verges between the extreme right of emphasis on current engineering techniques to the extreme left of nearly complete absorption of pure science. The Committee holds that heavy emphasis on pure science precludes the teaching of true engineering and that heavy emphasis on techniques promotes only the repetition of old tech-

[2] Report of Committee on Engineering Education After the War, Journal of Engineering Education, Vol. 34, No. 9 (May, 1944).

niques and does not promote the development of new ones. The aim should be a little left of center, toward the pure science side of the median point between the extremes, for engineering turns steadily toward more complex analysis and toward the employment of increasing amounts of science, and the colleges must lead in this.

3. *Social-humanistic subjects.* These are additional subjects aside from the technical and scientific part of the curriculum. It is their purpose to develop the student so that he may play the part of a citizen in local, in national, and in world affairs.

What composite constitutes engineering? The engineer must be able to operate in fields that physical science does not enter in a primary way—the human relationships of complex organizations, the operation of established processes with the full recognition of the factors of efficiency, of costs, and of quality. He must have a sense of practicality, resting upon a knowledge of established techniques and what they can be made to do. He must have a sense of responsibility to see a job through. He must have engineering judgment. The fusion of the recognition of a practical need, of orderly thinking in scientific terms, of newly applying scientific principles or applying new scientific principles, of applying approximations to situations where exact analysis is too difficult, of the reconstituting of old elements into a new combination providing a new result, of assessing the features of a process as to practicality in terms of the attendant circumstances relating to human relationships, to availability, to costs, and to markets, to the end that new, or better, or cheaper products be made available to industry and thus to society—this composite constitutes engineering.

Industry is rarely interested in employing a graduate for what he *knows* only; it is far more interested in what he can *do*. Not only that—his entire future is largely dependent upon his ability to continue to learn "on his own," both from study and from experience, after graduation. When the needs of industry and of the graduate himself are so clearly defined, it is the definite responsibility of our profession and of the colleges which train engineering students to cooperate in the engineering educational program.

Conclusion

The Committee on Undergraduate Curricula greatly appreciates the help it is receiving from interested members of the American Society for Engineering Education and will look forward to any further assistance in the way of comments or suggestions as its work progresses.

WEBSTER N. JONES,
Chairman

Recommended Visual Aids in Industrial Arts*

By HAROLD R. NISSLEY

and

THE CLEVELAND CHAPTER, SOCIETY FOR THE ADVANCEMENT OF MANAGEMENT

Because of the vast number of films produced during the war—some good, some not so good—a dozen or more catalogs are available, listing all or most of the 16 millimeter films produced in the last ten years. No attempt is made at evaluating any of these visual aids. A prospective user must, therefore, do some research if he is to get a film that will fit well into a program or put over a story.

It was to serve as a first course screen that a study was made by the Society for the Advancement of Management (Cleveland Chapter) to find out what management films were worth showing. Sixty-four educators in sixteen of the country's leading universities and a few management people were asked to list the best films in their respective fields. The response to this inquiry was so great that it was decided to break the study down into convenient "packages." One such package, "Recommended Visual Aids for Supervisors," appeared in the August issue of *Factory Management and Maintenance*. Another, "Recommended Visual Aids in the Field of Motion and Time Study," will be published shortly. This is the last in the series.

It is hoped that the following list of films, by no means all-inclusive, will be a more reassuring list than that offered by the typical catalog—that it will save the time of those responsible for getting up a program or integrated series of meetings. The reader should bear in mind that this list is merely a first screen; the chances are better for getting a suitable visual aid from this list than a random selection from a catalog. But the safest plan—always—is to view a film before showing it; such a preview will give the program chairman the possibilities and limitations of his visual "prop"; for what might be a good picture for one audience might be unsatisfactory for another group.

All films are 16 mm. unless otherwise specified. The running time on 16 mm. movies may be judged by multiplying the footage by 0.04 minute in the case of silent and 0.025 minute in the case of sound movies. Thus the running time for a 575 foot sound film would be around 14.4 minutes.

The films in this list had all shades of recommendations—from "fair" to

* Space will not permit full acknowledgment of all the help given in this survey. But I would like to mention at least three people who contributed most to the study: Mr. Daniel Vaughan and Miss Adele Masilonis, both of the General Electric Company; and Professor Judson Neff of the Graduate School of Business, Harvard University. The first two collaborated with the writer in the classification. Professor Neff had several hundreds of his cards in his film card file microfilmed; this Graduate School of Business file contains the data and professional comments on the majority of management and industrial films produced in the last ten years.

"excellent." It should be understood, further, that a film might be "excellent" for a group of foremen but might not be good for a group of college freshmen. Thus this list of recommendations should serve merely as a first screen to anyone setting up an integrated program. It is hoped, then, the following list will save the time and expense of frequent inspection trips and in other ways augment the teaching skill that is required during these days of large classes and insufficient faculties.

Recommended Visual Aids in Industrial Arts

Glass

Title	*Source*	*Recommended By*
Romance of Glass, The Sound, 1250 ft.	Pittsburgh Plate Glass Company, Pittsburgh, Pennsylvania	J. Neff, Harvard
You and Owens Sound, 950 ft.	Owens-Illinois Glass Co. Toledo 2, Ohio	J. Neff, Harvard

Machinery

Title	*Source*	*Recommended By*
Turret Lathes Sound, 1200 ft.	Gisholt Machine Co. 1245 E. Washington St. Madison, Wisconsin	R. S. Lindenmeyer, Northwestern
Turret Lathes--Their Operation and Use Sound, 1600 ft.	Gisholt Machine Co. 1245 E. Washington St Madison, Wisconsin	H. P. Goode, Stanford
War Against Waste Sound, 935 ft.	Caterpillar Tractor Co. Peoria 8, Illinois	J. Neff, Harvard

Machining

Title	*Source*	*Recommended By*
Charing and Operating a Cupola Sound, 450 ft.	U. S. Office of Education, Washington, D. C.	J. Neff, Harvard
Chips Sound, 1200 ft.	Warner and Swasey Cleveland, Ohio	H. P. Goode, Stanford
Countersinking, Counterboring and Spotfacing Sound, 725 ft.	U. S. Office of Education, Washington, D. C.	J. Neff, Harvard
Double Ram Vertical Surface Broaching Sound, 1000 ft.	U. S. Office of Education, Washington, D. C. (Castle Films)	J. Neff, Harvard
First Principles in Grinding Sound, 1550 ft.	Educational Service Dept., Carborundum Co., Niagara Falls, N. Y.	J. Neff, Harvard
How to Machine Aluminum Sound, 1200 ft.	Aluminum Company of America, Pittsburgh, Pennsylvania	H. P. Goode, Stanford
Locating Holes, Drilling, and Tapping in Cast Iron Sound, 600 ft.	U. S. Office of Education, Washington, D. C.	J. Neff, Harvard
Single Ram Vertical Surface Broaching Sound, 950 ft.	U. S. Office of Education, Washington, D. C. (Castle Films)	J. Neff, Harvard

Oil

Title	*Source*	*Recommended By*
Sincerely Yours SOUND, 950 ft.	Sun Oil Company 1608 Walnut Street Philadelphia, Pa.	J. Neff, Harvard
10,000 Feet Deep SOUND, 750 ft.	Shell Oil Company 787 Commonwealth Ave. Boston 15, Mass.	J. Neff, Harvard
Under the Hood SOUND, 1500 ft.	Socony Vacuum Oil Co. 205 Sixth Avenue Cambridge, Mass.	J. Neff, Harvard

Plastics

Careers for Cellulose SOUND, 875 ft.	Hercules Powder Co. Wilmington, Delaware	J. Neff, Harvard
Origin and Synthesis of Plastic Materials SOUND, 640 ft.	U. S. Office of Education, Washington, D. C.	W. A. Wittich, U. of Wisconsin
Plastics SOUND, 2000 ft.	Breskin Publishing Co.	R S. Lindenmeyer, Northwestern

Rubber

Building of a Tire, The SOUND, 950 ft.	Firestone Tire & Rubber Co. Akron, Ohio	J. Neff, Harvard
Rubber Goes Synthetic SOUND, 700 ft.	Colonial Beacon Oil Co 278 Stuart Street Boston, Mass.	J. Neff, Harvard

Steel

Bridging San Francisco Bay SOUND, 1600 ft.	U. S. Steel Corp. Film Distributing Center, 71 Broadway New York, New York	J. Neff, Harvard
Making and Shaping of Steel, The SOUND, 70 ft. SILENT, 105 ft.	U. S. Steel Corp. 71 Broadway New York, New York	H. P. Goode, Stanford W. S. Karabag, U. of Pa. J. Neff, Harvard W. A. Wittich, U. of Wisconsin

Other Metals

Magnesium, The Miracle Metal SOUND, 1420 ft.	Atlas Educational Film Co., 1111 South Blvd. Oak Park, Illinois	J. Neff, Harvard
Metal Without an Equal SOUND, 700 ft.	Ampco Metal, Inc. Milwaukee, Wisconsin	J. Neff, Harvard
Sand and Flame SOUND, 800 ft.	General Motors Detroit, Michigan	J. Neff, Harvard
Story of Metal Bellows, The SOUND, 1100 ft.	Fulton Sulphon Company Knoxville 4, Tennessee	J. Neff, Harvard

Textiles

Title	*Source*	*Recommended By*
Facts About Fabrics SOUND, 875 ft.	E. I. DuPont de Nemours and Co., Inc. Wilmington, Delaware	J. Neff, Harvard
Rayon, A New Frontier of Progress SOUND, 1600 ft.	American Viscose Corp. 350 Fifth Avenue New York, New York	J. Neff, Harvard

Welding

New Horizons in Welding SOUND, 1000 ft.	Harnischfeder Corp. 526 Statler Office Bldg. Boston 15, Mass.	J. Neff, Harvard
Unionmelt Welding—An Electric Welding Process SILENT, 300 ft.	Linde Air Products Co. 1517 Superior Avenue Cleveland 14, Ohio	J. Neff, Harvard

Miscellaneous

From Mine to Market SOUND, 1600 ft.	Phelps Dodge Corp. 40 Wall Street New York, New York	J. Neff, Harvard
Story of Shoes SILENT, 800 ft.	Medville Shoe Corp. 25 West 43 Street New York, New York	J. Neff, Harvard
Sugar SOUND, 1025 ft.	U. S. Beet Sugar Assoc. Business Films 2153 K Street, N.W. Washington, D. C.	J. Neff, Harvard

ECPD Resumes Accrediting of Engineering Curricula

A three-year program of re-inspection of engineering schools for the purpose of accrediting engineering curricula was announced by D. B. Prentice, President of Rose Polytechnic Institute and retiring chairman of the ECPD's Committee on Engineering Schools, at the annual meeting of the ECPD in Montreal, October 24 and 25. Committees have been selected and the program of re-inspection is now under way in some parts of the country. This work will continue under the direction of H. T. Heald, President of Illinois Institute of Technology, who succeeds Dr. Prentice as chairman of the Committee on Engineering Schools.

An objective of the accrediting program is the establishment of "criteria for colleges of engineering which will insure to their graduates a sound educational foundation for the practice of engineering." It is also an objective of the ECPD to "establish and maintain an authoritative list of accredited engineering curricula to be available to state licensing boards, the engineering profession, educational institutions, prospective students, and the general public."

Inspection is made upon invitation from the institution desiring to be considered for accrediting. Visiting committees, selected on the basis of the curricula to be considered, inspect the school and report their findings to a regional committee which, after consideration of all available information, submits its tentative recommendations to the Committee on Engineering Schools. The final decision of accrediting rests with the ECPD In chemical engineering, the inspection committees are selected by the American Institute of Chemical Engineers in collaboration with the ECPD's Committee on Schools. The findings and recommendations are then reported to the Committee on Schools of the ECPD. A curriculum may be fully accredited, provisionally accredited, or not accredited. Published lists include only the first two categories. Provisional accrediting is based upon conditions which the ECPD has found not to be satisfactory, but which the institution has given satisfactory evidence of remedying in the near future.

The ECPD has no desire or authority to impose any restrictions or standardizations upon engineering colleges. In fact, it is a stated policy of the ECPD to avoid rigid standards and to encourage well-planned experimentation. The original accrediting program was carried on from 1935 to 1937. It was planned at that time to re-inspect each institution at intervals of from three to five years. Because of the war, however, inspection was held to a minimum during the past five years. The Committee recognizes the fact that abnormal post-war enrollments complicate the operation of engineering colleges and may impair the effectiveness of instruction, but it is believed that the benefits which can be derived by a new accrediting program justify proceeding with the reinspection under present-day conditions.

A program of inspection and accrediting of technical institutes will be inaugurated by a Subcommittee on Technical Institutes headed by H. P. Hammond, Dean of the School of Engineering, Pennsylvania State College. Technical institutes which claim to produce qualified engineers or which grant baccalaureate degrees will not be recommended for accrediting by the Subcommittee on Technical Institutes.

Of the 167 degree granting institutions in the United States, 143 have been inspected (not including re-inspections) and 134 have one or more engineering curricula accredited. At the present time, 508 curricula in various schools have been fully accredited, 80 provisionally accredited, and 104 not accredited.

The Measurement and Guidance Project, under the direction of K. W. Vaugn, is proceeding on a program of four levels of examinations. These include: (1) an Engineering Science Aptitude test suitable for the guidance of secondary school students at the sophomore level, (2) the Pre-Engineering Inventory tests for students who have completed secondary school education and are contemplating taking engineering, (3) a series of Engineering Achievement tests for sophomore engineering students, and (4) specialized examinations for graduates of the various branches of engineering. The Pre-Engineering Inventory tests are now used by over fifty engineering schools as an adjunct in the selection and guidance of freshman students.

A proposal has been made by a committee appointed by the Carnegie Foundation for the Advancement of Teaching to consolidate the principal examining agencies into one cooperative non-profit testing organization. This organization would embrace the College Entrance Examining Board, the Cooperative Testing Service of the American Council on Education, the Graduate Records Office, the Measurement and Guidance Project of the ECPD, and others. In order to maintain its present position in the engineering achievement testing program, ECPD has accepted membership on the Council of the American Council on Education. Such a cooperative testing agency would avoid costly duplication of automatic tabulating machinery needed to score the tests and would serve to pool the experiences of experts in the testing and guidance field.

The Committee on Student Selection and Guidance of the ECPD, headed by C. J. Eckhardt, is distributing posters to secondary schools and college preparatory schools giving information on the personal qualifications and preparation necessary for success in a career of engineering. These posters supply much needed information for the self-appraisal of secondary school students who are contemplating engineering as a career.

The newly elected officers of the ECPD include J. W. Parker, chairman; H. S. Rogers, vice chairman; A. B. Parsons, secretary; S. L. Tyler, assistant secretary; E. H. Robie, chairman of the Committee on Information; C. J. Eckhardt, chairman of the Committee on Student Selection and Guidance; H. T. Heald, chairman of the Committee on Engineering Schools; Scott B. Lilly, chairman of the Committee on Professional Training; Ole Singstad, chairman of the Committee on Professional Recognition; D. C. Jackson, chairman of the Committee on Principles of Engineering Ethics; and H. P. Hammond, chairman of the Subcommittee on Technical Institutes.

A Machine Tool Designer's Thoughts on Engineering Education*

By B. P. GRAVES
Director of Design, Brown and Sharpe Mfg Co

LIMITATIONS TO OUR PROPOSALS

Although there are probably many of your students who would enjoy this opportunity of telling you what should be done with engineering education, it is an assignment which a mature machine designer hesitates to accept. I cannot tell you specifically what to teach, nor can I suggest how to teach it. At best I can but draw some broad conclusions from observations of engineers who have worked, and are working with me.

Perhaps I can take a cue from an inquiry we recently received for a large straight edge. It was a routine request for an 180 inch straight edge except that it contained the startling clause "guaranteed not to sag." No suggestion as to how a straight edge can be prevented from deflecting. No comforting admission that .0005 or less, would be considered as good as no deflection. Not even a comment on the possibility of ever attaining the goal—just the blunt specification "Guaranteed not to sag."

I hope this was not one of your students serenely ignoring all you had taught him about the modulus of elasticity. Whoever it was, this inquiry has suggested that I might describe to you the end result we would like to see in a young engineer after you have finished teaching him. How to get him to this state; what to teach him, and how to teach it, are your problems. Like the non-sagging straight edge, it may even be that the end is impossible of attainment, but unlike the inquiry, we are willing to allow you a liberal working tolerance and won't insist on a guarantee of perfection.

BACKGROUND FOR PROPOSALS

Since my views on engineering have been developed from a life-long association with the machine tool industry, it might be well to speak briefly about this industry to give a little background to my views. The industry, although the backbone of this mechanical age, is a small one. Its plants are not set up with endless assembly lines and it produces in lots of 1 to 50 rather than in millions. Its engineers must be versatile—prepared to work on all the problems presented by a machine, and on the partially related problems of such different machine tools as Grinding Machines—Milling Machines, and Automatic Screw Machines. Single Machines or small lots or machines cannot carry the costs of exhaustive studies, and a machine tool designer is limited in the time he can devote

* Presented at the Mechanical Engineering Conference of the A.S.E.E., Minneapolis, June 18-21, 1947.

to his particular assignment. He must have a good knowledge of fundamentals and must use this knowledge in making many decisions where exact information is lacking. For example: a designer must recognize the points where stress concentration will exist—must know the design steps to reduce its effects, and yet may never know just what the stresses are in the case involved for the cost of lucite models and strain gage investigations can rarely be carried by a single machine tool order, although we are doing much along these lines on our standard machines.

Fundamentals—the Starting Point

With this background, our first demand is for young engineers with a thorough training in the fundamentals of engineering. Men who know their mathematics, physics, mechanics, strength of materials, and the theory of structures so well that they have confidence in their knowledge and when faced with a new problem, will fall back on this basic knowledge and begin their analysis from there. In our industry there are hundreds of problems and fields of design which are not covered in college courses. No engineering school has courses in milling cutter design and few students have heard about clearance, rake, and spiral angles. We do not think you should give courses in milling cutter design, but how are you going to prepare the young engineer who must take up this work? The surest way of helping him is to ground him in fundamentals. Make him so sure of his mechanics and force analysis that he won't get lost in the complex forces which act on cutter teeth. Ground him in the basic concepts of heat; the conversion of work to heat, and the flow of heat through a mass and from one medium to another. We can give him details and help him on from here, but best of all, with such a basic training he can go forward himself.

As we began a new program of applying electrical controls to machine tools we were faced with many problems in design. No College had ever considered these problems in their courses and in many cases the answers weren't known. The engineers assigned to the job were qualified only if they knew the fundamentals of engineering and were prepared to proceed from there.

A typical problem which bridged the fields of mechanical and electrical engineering was the design of a high-speed viscosity switch. In the operation of a milling machine there are some actions which must be controlled by the direction of motor rotation. For example: When a milling cut is completed, it is desired to reverse the direction of table motion and to return to the loading position at quick traverse speed. If the cut is a blind one, or one approaching a shoulder, it is imperative that the reversal precede the shift to quick traverse. If this sequence is upset the table jumping forward at quick traverse rate will jam the work into the cutter and cause a smash-up. To be certain the desired sequence of actions is never violated, a viscosity switch can be used and through it the direction of motor rotation can open and close control circuits. This was a simple solution except for the fact that there weren't any successful, high-speed viscosity switches. A few bulky, low-speed devices were on the market but nothing of small size that could be operated directly on a 3600 RPM motor shaft. No courses

electrical or mechanical, cover the design of viscosity switches; no text book discusses the principles of design, or ventures empirical rules. Faced with design problems of this type, an engineer must depend on his knowledge of engineering fundamentals. Backed up with the ability to calculate the viscous drag of an oil film and a knowledge of the generation and dissipation of heat and its influence on viscosity, an ingenious designer can work out an acceptable design. With a sketchy knowledge of fundamentals, a designer will have a discouraging record of tries and misses.

Hundreds of similar design problems can be found in our industry; Small Tool design, gear pump design, hydraulic motors, grinding machine spindles, high-speed chain drives, etc. You do not teach these subjects in school—it would be an impossibility to try to cover them. The only help you can give a young engineer who must work in these fields is to ground him in fundamentals. Repeat, emphasize, hammer away, at the fundamentals.

You know, I know, all good mechanics know, even some of your students know, that you can't slide a thin washer along a shaft by pushing at one point on its outer edge. The washer is self-locking, the fundamental analysis is simple and your students can probably draw the free body diagram. For all this I would still claim that you haven't done a thorough enough job of getting across the fundamental concepts. I can show you at least four variations of this problem where engineers have fallen into the self-locking or near self-locking trap. A V-plunger pushed by slow-moving table dogs, single shoe shifting forks moving splined clutches, short lands on intermittent gears, and small pinions journaled in large bearings. Give the problem some new clothes and the young engineer hasn't a firm enough grasp of the fundamentals of friction analysis to see trouble spots. We have spent hundreds of design hours and thousands of dollars planning and making corrections just because designers did not or could not draw free body diagrams and unknowingly let friction forces get out of line with applied forces.

I always hesitate a little when I get on the subject of friction for it suggests a group of our designers who were standing around a new machine looking at a mechanism which wouldn't work correctly. One designer was explaining that there was too great a difference between the static and kinetic friction coefficients and for that reason operation was erratic. An old-time mechanic who had assembled the machine rather bluntly interposed with "I don't think that's it." The designer, irritated, said "Why Ceorge I'll bet you don't know what static friction is." "Oh yes I do—that's what wears the seats out of the pants of the Engineering Department."

Rigidity

It is quite obvious to designers that parts must be so proportioned that they will not be overstressed by working loads. Designers are far less aware of the necessity of proportioning parts to control deflections which occur under these loads. In the machine tool industry more design decisions are based on rigidity than on strength. Because of this, I believe more attention should be paid to the analysis of deflection in machine design courses.

One of the first deflection problems in machine tools is described in the

book "English and American Tool Builders" by Professor Roe from which I quote the following:

"Watt had been working for several years on the steam engine when the idea of a separate condenser came to him on that famous Sunday afternoon walk on the Glasgow Green in the Spring of 1765. Watt was a skilled instrument maker and his first small model was fairly successful, but when he undertook 'the practice of mechanics in great' his skill and all the skill of those about him was incapable of boring satisfactorily a cylinder 6" in diameter and 2' long. For ten weary years he struggled to realize his plans in a full-sized engine. His chief difficulty lay in keeping the piston tight. Small wonder—for we find him complaining that in an 18" diameter cylinder at the worst place, the long diameter exceeded the short by ⅜ of an inch.

"Fortunately in 1774, John Wilkinson hit upon the idea of making the boring bar heavier, running it clear through the cylinder and giving it a fixed support at the outboard end."

With cutting tool deflection under control, it was possible to bore cylinders "almost without error" so that one of 50 inch diameter "did not err the thickness of an old shilling in any part."

The relationship between machine rigidity and accuracy of work suggested by Wilkinson's boring machine has been an important factor in every machine tool ever built. Modern machine tables or slides cannot be positioned with accuracies of .0001" unless table screws, screw thrust bearings, and supporting brackets are designed to deflect less than .0001. Machines cannot produce surfaces of fine finish with micro-inch readings below 10 unless wheel spindles and work supporting members have good rigidity and can keep their relative positions within this .00001 figure. Machines cannot produce work flat and square within fractions of thousandths unless machine ways can hold their alignments under shifting loads.

An engineer working on fine measurements or a designer working on small tools almost forgets the problem of strength and is instead forever concerned with the problem of rigidity. No one ever worries about whether a micrometer will break, whether a dial indicator post will snap, or whether a surface plate will be overloaded, but if any one of these deflects by .0001" it may be a failure worse than breakage. After all, there is something nice and positive about breakage, but a little error from deflection can quietly slip into your measurements and give you nervous exhaustion trying to reconcile repeated readings.

There is one specific deflection problem which I find generally ignored. That is the problem of the relative deflection of a journal and its bearings. Students will make lengthy calculations of load-carrying capacity, heating, location of oil inlets, and never suspect that deflection may make these calculations useless. Look at the hundreds of books and papers on plain bearing design and you will see that students are not alone when it comes to the neglect of deflection analysis.

We appreciate the problem when we consider the design of plain bearing grinding machine spindles. These bearings lubricated with water thin oil (32SSU) and operating with a radial oil space of .0001 to .0002, are very sensitive to deflection. The overhanging loads produced by the grinding wheel on one end of the spindle and the V belt drive at the other end, can easily give a spindle enough slope to make it touch, metal to metal, on opposite ends of a bearing. A student

impressed by the proportions usually shown for bearings or placing trust in the empirical rule that length should be two or three times the diameter, is likely to get into trouble.

If you would have your students earn more than an "old shilling" when they graduate, and if you would help us preserve for our machines the title "The Master Tools of Industry" then teach deflection analysis as rigorously as you teach stresses, and make your students as conscious of the problems of deflection as they are of breaking loads.

Unity

The second recommendation I would like to make is that Engineering Schools do a much more thorough job of integrating and coordinating their courses. The fundamentals of mechanics, physics, and strength of materials, should be more carefully traced through the advanced courses. Courses do not exist by themselves. They should show a strong thread of development from the fundamentals and should show the relationships between courses. In this way, the whole engineering program can be given some unity.

For more specific discussion we might consider a machine design course. It would be my suggestion that the course be set up to show how the fundamental courses, the basic tools of engineering, may be used in machine design. It should show a student how, by using force analysis, dynamics, strength of materials, etc., he can work out good designs. The course would not set up a new and different world with magic formulas and glimpses of practical know-how, and it would never be a haven for those students who sigh with relief that the theoretical and time-wasting courses in physics and mechanics are over. The course instead would show how the basic ideas covered in the earlier engineering courses, are the foundation of design. For all their complexity, gears are problems in uniform motion, the contact stresses of convex surfaces, the bending stresses of cantilevers and fatigue life under these stresses. Clutches and brakes are problems in friction, energy and heat, wear, and the nice force analysis of self-actuation. Ball and roller bearings are problems in stress and deflection and the basic principles of design hold true in all the many series that are offered.

This dependence on fundamentals can be found in all the subjects of design you teach. If you high light these fundamentals and show the strong thread of development from early courses through the design courses, you can give some unity to engineering education. A student would have a good chance to make practical use of the fundamental courses and would complete a design course with a clearer, surer knowledge of mechanics, physics, and strength of materials.

The coordination of courses and the broad application of basic ideas were called to my attention in a simple example. The reversing clutches on the spindles of automatic screw machines have been carefully studied and analyzed. We have understood the basic concept that in bringing a body up to speed with a friction clutch, you must waste in heat, an amount of energy equal to the kinetic energy which the body will have when it reaches top speed—that the energy lost in a complete reversal from full speed in one direction to the same speed in the opposite direction, is four times the kinetic energy of the body and that this is

twice as much lost energy as would be involved if the spindle could be braked to rest and then accelerated to speed. These relationships were also understood to hold regardless of whether clutch torque was large or small, constant, or variable.

Now in close work with our electrical engineer on the problem of the permissible frequency of table operation on a machine tool whose driving motor starts, stops, and reverses with the table, we were surprised to find him estimating motor heating with the same basic energy relationships. The energy lost in starting was equal to the final kinetic energy of the motor rotor and the connected members. One reversal was four times as bad from the point of view of heat as one start and one plugging to rest, stop was three times as bad as a start. This was talking our language and these were the basic relationships we had forced ourselves to recognize on screw machine spindles.

No college courses ever showed us these simple relationships. As far as college was concerned electric motor design and machine design were taught in different languages. I think both courses should have been hammering away on kinetics and developing basic ideas.

To encourage coordination of courses, I would go so far as to suggest that each Professor be asked to sit in as a student on at least one course a year just to let him see the similarities between the things he teaches and those being taught by others. Perhaps teachers would see why students spend so much time trying to make equations of inch-minutes and foot-seconds balance. Perhaps the machine design instructor could see a little closer relationship between the theory of structures and some of the deflection problems in machine design. Perhaps the mechanics Professor could make his own course more useful if he saw what a mechanics problem looked like when it gets all dressed up in the complexities of a civil engineering problem. It would do the electrical engineer much good to sit in on a physics course and learn that basic ideas got started long before the first patents were issued. And how we all would enjoy watching the physics professor trying to wring a few units with which he usually works. honest horsepower from the maze of

This is probably make-believe, but I do wish that men would begin to see the similarities between courses and become more aware of the fundamentals which carry through all courses. Students need greater unity in their Engineering Education.

When it comes to "sitting in" I would like to venture one more suggestion, and that is—that Instructors and Junior Professors be encouraged to spend some part of their Summer in industry, and that this engineering work be given the same status as Summer research or writing. I know there is a vast difference between practical problems and boow problems, and if you are to prepare men for industry, then you must know what is required and the best way to obtain this information is by practical experience.

Sometime ago this difference in relationship was brought out by an engineer in a simple illustration—of changing an automobile tire in the garage to changing a tire on a narrow, highly-crowned, soft-shouldered road on a rainy night. None the less the experience would be vivid and your teaching would be more interesting because of the experience. Someone aptly described a "minor operation" as "an

operation performed on somebody else." So it is with classroom examples. The fatigue break which you investigated can become a much more lively subject in class discussion than the impersonal textbook example and the beam of uniform strength you designed for a feeding finger can be a more convincing illustration of design analysis than the colorless skeletons usually cited in the handbook.

In order to prove that the student is getting all these fundamentals that are necessary for correct machine design, as well as to get him into the habit of looking up factual matters, I would suggest that you put more of your effort to teaching logical thinking, analytical methods of solution, and critical selection of the results. My suggestion to attain this is to prepare practical individual questions or problems for each student to work out, which to my mind will cultivate more original thinking and at the same time, prove whether or not your student has been well grounded in the fundamentals. I feel that this method will also prove your student's creative ability, which is one of the factors most essential in machine design. This I know I will take more time on the part of the Professor, in preparing his class work—it will also prove more laborious in correcting papers because of the fact that the student has more latitude in working out his problem, but I feel quite certain that this method will create more interest among your students outside of his classroom, as students will become interested in each other's problems. I definitely feel any student who is interested enough to take the machine design course must have a definite liking for this field and by giving them individual practical problems, is certain to keep their interest alive.

Breaking away from education but still thinking of unity and coordination, I have the opinion that one of the serious criticisms of our technical literature today, especially of the papers published by our large engineering societies, is that they do not show interrelationships. There is too much emphasis on the aspect that—this is new—different — a startling departure — a revolutionary development. I think the emphasis should be in the other direction of establishing similarities and showing how fundamental concepts have been used. The maze of material being presented these days needs simplification. I know of no better way of getting it than by making authors more conscious of the unity that exists in engineering subjects. I do not expect you to correct this bewildering condition for us and I have mentioned the problem solely to point out that we need more unity in our engineering thinking and that you can give students lasting help if you can give them a well coordinated or unified education.

To conclude this talk, I need only to warn you that if you teach a boy the design of punch presses, we shall probably put him to work on sewing machines. If you prepare him in internal combustion engines, we shall most likely ask him to lay out a centrifugal pump; and if you teach him electric generators, there is a good change he will spend his days trying to determine which millionth of an inch a strain gage is indicating. You can help these boys most if you ground them in the fundamentals and give them a unified knowledge of engineering.

If you work out such a program, let me know—I need the course myself.

Discussion on Mr. Graves' Paper

Prof. A. H. Burr, of Northwestern University: In design of a particular machine does not the student learn principles common to all machines? Should specific design problems be carried out in classrooms?

Mr. Graves: Yes. Fundamentals can be taught by means of interesting design projects. Probably simpler problems are better than long complicated ones to teach fundamentals effectively.

Prof. E. N. Baldwin, of Penn. State: Can you give us other specific cases of student pitfalls in application of fundamentals?

Mr. Graves: (Showed prints of gear problems, indexing mechanism, and bearing problems.)

Prof. W. J. King, Cornell: Is emphasis on appearance-design general in the machine tool field? Are texts available?

Mr. Graves: Brown & Sharpe has a small group of industrial designers working on appearance design of products. I know of no particular texts and those in existence are too specialized and individualistic in styling and often impractical. Functional requirements are paramount to appearance.

Prof. M. S. Gjesdahl, Penn. State: What proportion of time should be devoted to drafting practice in engineering curricula?

Mr. Graves: Not too much time as we can give adequate training in drawing and do not keep engineers on drafting work for more than a short period.

Prof. P. H. Hyland, Univ. of Wisc.: What can schools do to overcome student dislike for drafting? Do all companies move engineers through drafting rooms as fast as possible?

Mr. Graves: The companies of my acquaintance follow a policy similar to ours. Our engineering and drafting departments are separate and have no engineers on permanent drafting.

——————: What do you do with young engineers who do not prove to have proper qualifications for advancement out of drafting?

Mr. Graves: We come to a definite understanding with such men and do not encourage them to remain with us if they cannot so advance? (We may move him into another division if he looks like good material, such as factory or sales.)

Prof. T. P. Colbert, of Bradley: Our schools have an industrial arts course. Should not such training be specifically an arts course and not pretend to be engineering?

Mr. Graves: Yes, the arts and engineering should not be confused but common fundamentals in either case should be stressed. The industrial designer needs to have an artistic viewpoint.

Prof. Bradley: Should we train tool designers in special courses?

Mr. Graves: No. My personal opinion is that no such special courses are necessary. I would place a graduate in tool engineering in the tooling department and his chances for advancement as an engineer would be slight.

Prof. H. K. Palmer, Univ. of Minn.: How far should we go in design details?

Mr. Graves: Stick to fundamentals.

Prof. Palmer: Won't lack of knowledge of details and detail drawings be a handicap to a boy?

Mr. Graves: I do not expect him to be an expert on details, or drafting,

only to have a sound command of fundamentals of engineering. We can readily teach him detailing and system.

PROF. BRADLEY: Kinematics instruction on the inversion of mechanisms stimulates creative thinking.

MR. GRAVES: I do not think this method stimulates creative thinking any more than other methods, and unless it is handled correctly, may become involved.

PROF. CAYWOOD, of Univ. of Iowa: Would you approve of any tool design course?

MR. GRAVES: No. A knowledge of mechanics is sufficient. Our tool designers are usually taken from the drafting room force. If we require a graduate engineer in our Tool Design Force, we can teach him if he has engineering fundamentals.

PROF. BALDWIN, of Penn. State: Have you any. suggestions as to coordination of courses in materials properties?

MR. GRAVFS: Each type of industry has its individual problems and metal specialists must handle this. Young engineers receive their training from these specialists, either direct or through their Chief Designer.

Mathematics in Civil Engineering

By JOHN M. HAYES
District Bridge Engineer, Little Rock, Ark.

The writer has always been interested in engineering education and was greatly attracted by two articles, which recently appeared in THE JOURNAL OF ENGINEERING EDUCATION—"Mathematics in Civil Engineering," by Harold E. Wessman, January, 1947, Vol. 37, and "Teaching Mathematics to Engineers," by L. E. Grinter, March, 1947, Vol. 37. He thought that possibly comments upon this subject by a civil engineering practitioner would be of interest to engineering educators, for whom he has the greatest of respect and admiration.

Mathematics is one of the most powerful tools that the engineer has at his disposal. It is fundamental in the development of the basic theory in any branch of engineering. It is inconceivable that any teacher of strictly engineering subjects should not realize the importance of a thorough grounding in pure mathematics, and with a fair degree of rigor too. Yet many do not seem to realize its importance. It is easier to understand why the average engineering practitioner belittles higher mathematics, and by higher mathematics, is meant anything above simple algebra, simple trigonometry, and simple analytic geometry. Most engineering students have completed their formal study of mathematics by the end of their sophomore year and very little mathematics, other than simple algebra and trigonometry, is used in conjunction with their junior and senior engineering studies. Possibly calculus is used to define the slope and deflection of a beam; but, from the amount of calculus that is used, many engineering students often doubt the necessity of its study. Most civil engineering students are, therefore, not very conversant with calculus and the higher reaches of algebra and trigonometry by the time they graduate. Many of them have not had the importance of mathematics pointed out to them by their engineering teachers. Then the positions that they hold for the first few years after graduation are usually of a routine nature and require only a knowledge of simple mathematical operations. At the end of this period these young engineers are beginning to become strangers with anything but these simple mathematical operations. By the time they are confronted with problems that could be solved more easily and quickly by the use of higher mathematics, they are indeed strangers with the subject. Instead of reviewing their mathematics, they belittle its importance and look with scorn and amusement upon anyone who is interested in the subject. It is surprising how many develop this viewpoint. They do not realize how much time can be saved

by the use of higher mathematics in the solution of many fairly commonplace problems, and they are lost for an exact solution of the more intricate ones. They are scared at the sight of an integral sign that appears in the literature published in the proceedings of their engineering societies and are prone to say, "who reads it anyway." To this group is gone the opportunity to delve into the fundamental theories of their profession. How could anyone get into the interesting fields of the theory of elasticity, the theory of elastic stability, or higher hydraulic theory without a partial understanding and appreciation of higher mathematics?

The problems encountered in the computation of quantities for engineering estimates are usually solved by the use of simple mathematics, but the use of higher mathematics would often result in a great saving of time. The series can be used to great advantage in the solution of many practical problems, but they are considered as higher mathematics and the average engineering practitioner is again lost in the use of this most valued tool. For instance consider a problem involving a horizontal cylinder partially full of water, where it is desired to develop a general equation for the varying water pressure acting circumferentially around the vessel. The easiest way is by the use of a Fourier series, but again this is higher mathematics.

What is the answer to this matter? With all of the talk about the broadening of engineering curricula, it is not easy to say. It is thought that mathematics should be taught by professional mathematicians who, as Professor Grinter points out, should impress upon the student the fact that mathematics is "a useful tool, in fact the most powerful of all scientific tools," and "would never let the engineering student forget that fact for a single moment." Such a teacher would cite practical applications whenever and as often as possible. He would gradually impress upon the student that he needs mathematics and that he can use it to his advantage. The writer agrees with Professor Wessman that each branch of mathematics should be taught as separate courses, as conventionally grouped, and not as scrambled unified courses. The engineering teachers should use mathematics in the development of the theories of their subjects and impress the student of its utilitarian value and the importance of its continuous review in order to keep a working knowledge of it at his finger tips. This is pointed out by Professor Wessman when he writes, "There is a value in overturning the mathematical tool kit occasionaly in order to get acquainted with the best tools for the various engineering problems which occur in practice." In passing it would be well to emphasize the obligation of the engineering teacher to frequently advise the student of the importance of continuous and further study of his engineering subjects and to impress him with the fact that the "commencement" at the end of formal undergraduate training means only that the graduate has a few tools with which to further his study. In design courses more emphasis should be put upon the mathematical development of the fundamental theories and the background of specification requirements rather than blindly designing some typical structure in accordance with the provisions of standard specifications.

It would be highly desirable, and of benefit to many civil engineering students, if a year of higher mathematics could be included in the undergraduate

curriculum. However, the conventional amount of mathematics now included in the undergraduate engineering curriculum will undoubtedly stay about as it is for some time, with higher mathematics left for self-study or graduate work. Mathematics is one of the hardest subjects for self-study that most engineers encounter, so the importance of formal study in this field cannot be over emphasized, at least, until the student is familiar with the elements of higher mathematics. It is hoped that the future civil engineer will be able to make more efficient use of his mathematical training.

Comments on Army ROTC Programs

By P. B. NARMORE

Executive Dean, Georgia School of Technology

Down south in Georgia we have a saying, "Whenever two or more Presbyterians get together they pass the collection plate." For many years a somewhat analogous saying is to the effect that everytime two or more educators get together they discuss curricular matters. Usually this discussion in the past has concerned itself with the amount of social studies in the engineering curriculum. Today we are extending the discussion to Naval and Military courses and their place in engineering education. A number of Army and Navy officers want this discussion to continue and I am sure many engineering educators do, also. We realize the necessity and value of ROTC training on the college level, but we want it to keep pace with the changing needs of both engineering education and military training.

For many months our Federal Government has been studying the need for Universal Military Training. I am of the opinion that more discussion will be necessary if this national training program is adopted.

To understand some of the problems in the ROTC program it is necessary to consider some statistics. The Army program plans for training 210,000 students each year in comparison to the 14,000 Navy students, or about fifteen times as many as the Navy will train. The Army has fifteen different types of units and curricula in the advanced ROTC program. The Navy has one main curriculum, differing only in the last three semesters in the curriculum for Marines. In checking the number of ROTC units, I find that the following numbers are either established in colleges now or will be by July 1, 1947.

Engineers	35
Field Artillery	32
Army Security	2
Quartermaster	23
Transportation	14
Armed Cavalry	11
Seacoast Artillery	2
Medical	23
Infantry	103
Signal Corps	37
Ordnance	22
Air Corps	77
Chemical Corps	6
Military Police	8
Anti-Aircraft Artillery	18

Some educators believe that these fifteen units with their highly specialized curricula are too many, except possibly during time of war. Some schools have so many units now that they have difficulty furnishing space for equipment. The need for classrooms is increased considerably by increasing the number of units at a school. Display space for equipment also is increased according to the number of units. Certain specialized equipment is required for each unit whether it has 100 or 500 students. As an ex-

ample of the large number of units at individual colleges, I find

Texas A & M	has 12 units
Ohio State	has 9 units
Univ. of Illinois	has 8 units
Univ. of California	has 8 units
Massachusetts Tech.	has 7 units
Georgia Tech.	has 7 units

Returning now to curricular matters, one question that has been discussed informally concerns the refusal of the Army and Navy to substitute college courses for similar ROTC courses even though the college courses are taught by men with better training for teaching the subject. As an example, many of our Georgia Tech boys study a course in psychology as well as a course in personnel management. These courses are taught by trained instructors most of whom have either their Ph.D. degree or have had professional work in the field. Even though the ROTC could select their officers, it is expecting too much of such an instructor to compete with a professional psychology instructor. Still the ROTC requires nearly all of our students to take a course called "Military Leadership, Psychology, and Personnel Management." The scope of this course is as follows: Principles of psychology; psychology in battle; morale; personal attributes and professional qualifications of the leader; pride; rewards; punishments; etc. Practically all of these topics are covered in our college psychology course.

Many college courses in electrical engineering, including electronics, could well be substituted for Signal Corps courses. Chemical engineering courses could substitute for Chemical Corps subjects; aeronautical engineering courses could substitute for Air Corps courses; civil engineering courses could substitute for Engineering Corps courses. Accredited colleges should be permitted to substitute practical experience and comparable college courses when approved by the PMS & T just as any other department head may accept courses for substitution. The policy of non-substitution continues on up into the ORC and I believe it to be unwise.

Please pardon a personal experience which will explain my point. In my undergraduate ROTC I had been assigned to the Signal Corps because my general engineering course consisted mainly of electrical and mechanical engineering. The major subject for my masters degree was civil engineering. My doctorate was in engineering mechanics with a research problem supported by the Timken Roller Bearing Co. I later taught theoretical mechanics and strength of materials for ten years. In the meantime I had lost all contact with anything connected with the Signal Corps. This theoretical and professional experience closely allied with ordnance was not considered sufficient to permit transfer from the Signal Corps to the Ordnance Corps. The Army insisted that it would be necessary to complete some twenty odd correspondence courses before transferring.

A subject of interest is found in the following table which gives a comparison between professional courses in quarter hours as taught at Georgia Tech and the military requirement of 30–36 credit hours.

Dept.	Total	Soph	Junior	Senior
A.E.	46		9	37
Chem. Engr.	48		13	35
C.E.	58	8	17	33
E.E.	62	3	28	31
M.E.	53	4	21	28

Is this large number of ROTC hours necessary when there is duplication especially when we consider the professional courses are a necessary preparation for earning a living?

The requirements for a commission at Georgia Tech are considerably more than the average person realizes. Our students have military duties for 160 hours each year or a total of 640 for four years. Allowing an additional hour for preparation, 1,280 hours are required for military. If we consider 40 hours as a week's work, then 32 weeks are required. Adding six weeks for the ROTC camp, the total is 38 weeks. If we had allowed two hours preparation for each of the 640 hours, we would account for an equivalent of 52 weeks of work.

The results of a study as to how 35 outstanding colleges allocate time for ROTC recitation and drill are given in the following table.

Elementary Course

3R	4 Colleges
1R2D	4 Colleges
2R1D	13 Colleges
2R2D	3 Colleges
3R1D	5 Colleges
3R2D	4 Colleges
2R3D	1 College
3R3D	1 College

Advanced Course

3R	1 College (courses other than Arty.)
3R2D	7 Colleges
5R	4 Colleges
4R1D	14 Colleges
4R2D	3 Colleges
5R1D	4 Colleges
5R3D	1 (Military College)

About 40 per cent of the colleges give more time in the elementary course than the minimum of three hours required by the Army. Less than 25 per cent of the colleges give more time in the advanced course than the 5 hours per week required by the Army.

Another question sometimes discussed: Is it necessary for men in the professional schools to spend so much time on the drill field? Marching was important back in the days when the Infantry was supreme and when marching was the main mode of transportation. That day has gone forever, under mobilized transportation needed for rapid troop movements of men. Still our boys drill two hours a week in the basic course and once or twice a week in the advanced course. Any "poise" or "understanding of handling men" which may have been gained in the past is now largely supplied by required college courses in Public Speaking and Psychology. The only apparent value gained by drilling is that trainees may learn the need for coordination in group movements. This might be better supplied by war games.

One item of concern to college administrators outside curricular considerations is the difference in the Army and Navy methods of accounting for equipment. This equipment is usually located in the same buildings with the officers and is used exclusively by them. The Navy consigns all of their government property, including uniforms, to the professor of Naval Science. The Army requires that the college appoint a military property custodian to receive and account for all Army property sent to the college. This responsibility includes handling uniforms. Furthermore, a bond is required of the college to indemnify the Army against loss of any of its property. Since the PMS & T uses the equipment and prepares inventories for his own use, nearly all colleges appoint him as their property custodian. Nearly all colleges pay the ROTC staff well for this service which the Army should do themselves. The practice of making

schools responsible should be done only where they fail to provide reasonable property security.

In conclusion, I am sure I voice the sentiment of all gathered here that colleges have a patriotic obligation to work continually for improvement in the ROTC programs. With this feeling I believe then, that we should discuss such points as:

1. Is it necessary or desirable to have the large number of specialized corps, such as three types of artillery, during peace time.
2. The possibility of substituting college courses for military courses on the same basis that other departments operate.
3. The necessity for the large number of hours required in the military program as compared to the number of hours in the professional courses.
4. The advisability of reducing the number of hours spent on the drill field.
5. The Army requirement that colleges act as property custodians of military uniforms and equipment.

The Humanistic-Social Studies in an Engineering Education: Some Basic Fallacies

By MELVIN KRANZBERG
Amherst College

In an age of accelerated technological development it might be expected that attention would be paid only to education along technical lines and that studies dealing with man's social relationships and cultural expression would be slighted. Instead we find that even in those institutions dedicated primarily to the production of engineering specialists greater importance is being attached to the humanistic and social studies than ever before. The civic and professional responsibilities of the engineer are constantly stressed, and it has become a commonplace of commencement oratory to point out that the engineer is a citizen as well as a man trained to a high level of technical competence in a specialized field. The role of the humanistic-social studies is emphasized as giving the student that broad and liberal viewpoint, embodying some measure of social consciousness, which will encourage him to perform his duty to the community in all spheres of activity rather than only in the narrow one wherein his engineering ability is applied.

This realization of the part which the engineer must play in the modern world is, fortunately, not confined only to the speakers on the commencement platform. The engineering schools themselves have become increasingly conscious of this fact; their attempt to make it one of their primary objectives—in addition to the giving of an engineering education in the limited sense—is responsible for the enlarged interest in the humanistic-social studies manifested by the changes in curricula and by the large number of articles in the JOURNAL OF ENGINEERING EDUCATION dealing with that subject.

Despite the almost complete unanimity on the aim of converting the engineer into a well-rounded man rather than a narrow specialist and the need for the humanistic-social studies to achieve that end,[1] there exists no general agreement as to how these studies are to be employed to achieve the desired result. Some educators would teach non-technical subjects as they are taught in liberal arts colleges, maintaining that these essentials could be learned only if they are taught in their pristine purity, unsullied by any concessions to the special needs of an engineering student.[2] Others would make

[1] There are exceptions to this "unanimity." Cf. S. F. Borg, "Humanistic-Social Studies in Engineering—Another Viewpoint," *Journal of Engineering Education,* Vol. 36, March, 1946, pp. 424–425.

[2] Alfred C. Ames, "Should Humanistic-Social Study Be Made Engineering Education?" *Journal of Engineering Education,* Vol. 36, May, 1946, pp. 543–546.

the humanistic-social studies an integral part of the engineering curriculum by using engineering knowledge, tools, and ways of thought in those courses. In other words, they would use the non-technical fields of study to emphasize the attitudes and methods of thought which are a prerequisite for the strictly technical courses, while at the same time devoting them to subject matter of intrinsic value to engineers.[3]

It is unfortunate that, while decrying the specialization and compartmentalization of knowledge, these experts, by their emphasis either on keeping the humanistic-social studies separate from an engineering education or by intertwining them with such an education, have in most cases based their arguments on fallacious assumptions which presuppose the continued fragmentation of the fields of human endeavor. Even those specialists who realize that the humanistic-social studies, aside from the knowledge which they can impart concerning the world in which we live, can be used to inculcate the inductive approach and methods in solving problems which are employed in the engineering field, still relapse into the same errors against which they inveigh. They make a distinction between mathematical and "non-mathematical thinking" at the very moment they are trying to show that the humanistic-social studies can be used to reenforce and reproduce scientific thought.[4]

The fact is that our faculties of humanities and social sciences, as well as our technical professors, have allowed themselves to be "side-tracked" in their thinking on the question of the places of the humanistic-social studies in the engineering curriculum by preserving two concepts which have been outmoded for some time but which still maintain their hold on the popular mind and, evidently, on the minds of those who are attempting to integrate the sciences and liberal arts. These two traditional yet misleading concepts are those of the "scientific method" and the "scientific mind."

The engineers, the "applied" scientists, along with their blood-brothers, the "pure" scientists, have proudly claimed to be the sole possessors of a method which alone can perceive and pursue the truth, the so-called "scientific method." On the basis of this claim, our entire educational system, not only in engineering schools, has been broken up into segments based upon whether or not a certain method is supposedly applicable to a field of study. Furthermore, the non-scientific groups have been so intimidated by the engineer's mystical assumption of sole title to a method for the solution of problems that they have hesitated to employ the methods of the scientist. If the expert in the social studies ventures to use the techniques of the scientist, he apologizes for his seeming encroachment upon the sacred preserves of science. Quite unjustifiably he regards himself as an interloper or trespasser.

Actually, the so-called "scientific method" involves nothing more than the observation and collection of data, and its integration and interpretation on the basis of the perceived facts. There is no reason why this method and its basic attitude of detachment and objectivity should be considered the

[3] Elliott Dunlap Smith, "Can Humanistic-Social Study Be Made Engineering Education?" *Journal of Engineering Education*, Vol. 36, October, 1945, pp. 134–138.

[4] B. R. Teare, Jr., "Planning the Professional Aspect of the Humanistic-Social Courses," *Journal of Engineering Education*, Vol. 37, December, 1946, pp. 344–352.

exclusive property of the sciences. Other fields of knowledge can and have employed these methods and attitudes, as contributors to the JOURNAL OF ENGINEERING EDUCATION have pointed out in the past.[5] True, in the matter of human relations, the observation and collection of the data is made more difficult because of the lack of exact knowledge in some cases, the impracticability of precise measurements of social phenomena, and also because of the impossibility of repeating experiments insofar as historical events are concerned. But the fundamentals of the "scientific method" and attitude are applicable to all fields of human endeavor as well as to those which deal with the physical aspects of matter.

The concept of the "scientific mind" is another fallacy which has hampered the integration of the humanistic-social studies into the engineering curriculum. The implication of this concept is that engineers are people apart, possessing certain mental qualifications enabling them to deal with esoteric problems regarding the nature of the physical universe, but leaving them totally unqualified to deal with matters of an esthetic or social nature. Like all good geometrical theorems, this proposition has a converse, namely, that there are certain other people who do not possess a "scientific mind" and hence are incapable of understanding the problems and work of the engineers. The results of this distinction between the scientists and non-scientists can be seen in our entire American educational system, but nowhere are they more apparent than in the engineering schools, wherein this difference is employed to explain the shortcomings of both faculty and students. Thus the possession or lack of the "scientific mind" is advanced to explain the failure of the student who excels in physics to be able to write a simple English sentence properly, while the students assume—as do some of their colleagues—that the professors of literature are unable to add the balance in their checkbooks correctly.

This idea of the "scientific mind" is based on the false psychological assumption that there are various faculties existing in the mind which enable some people to do problems of a mathematical or scientific nature without difficulty, while others who have specialized in other fields are unable to add two and two. Not only have psychologists been unable to discover any separate portion of the brain devoted exclusively to items of a scientific nature, but it is questionable whether there are any differences in the mental processes involved in the solution of a physical equation or a problem of contemporary social relations.

In all cases, whether dealing with physical or social phenomena, our minds work with symbols to make known our ideas. In the case of the mathematician the symbols are numbers; with the physicist they are numbers and Greek letters which have been assigned an arbitrary value or meaning; with the chemist they are literal and numerical symbols; in the humanities and social studies, the symbols are words. In each case, the symbols are used to express ideas. Unfortunately, in the humanistic-social studies we are forced to use symbols which are used in everyday life and which have received no artificially designated value upon which there is complete agreement, such as, for example, the value of Pi to the mathematician. But that does not mean that the mental processes involved in expressing ideas

[5] *E.g.*, Ames, *loc. cit.*

through symbolic terms are any different for the physicist than for the student of the humanistic-social studies. Yet the engineering student often claims that he is unable to express a clear idea upon politics because of this supposedly inherent psychological distinction, even though we now know that a high level of general intelligence is usually a prerequisite for excellence in any branch of knowledge and that any special attitudes which one might possess in certain areas of mental endeavor would be attributable to environmental or social factors rather than inborn psychological characteristics.

If the false distinctions between those possessed of the "scientific method" and the "scientific mind" and those who lack these essentials are obliterated from our thinking about engineering education, we may begin to reconsider the whole problem of the place of the humanistic-social studies in the curriculum. When we have purged our minds of these traditional yet fallacious assumptions we may proceed to re-examine the philosophical bases of our educational thought in the light of the unity of all fields of knowledge.

Attempts have already been made in that direction, to one of which has been applied the name "Scientific Humanism,"[6] implying that there are no basic differences in the aims of the scientific and humanistic aspects of an engineering education. With the realization that the ends to be attained are the same for both elements of the curriculum, it should be possible to achieve an integration of the humanistic-social studies with the technical aspects of the engineering course that will satisfy the need for the production of an intelligent citizen without at the same time sacrificing the technical competence necessary for the engineer to perform his special work usefully to society.

[6] Edwin S. Burdell, "The Philosophy of Humanistic-Social Studies in Engineering Education," *Journal of Engineering Education,* Vol. 37, April, 1947, pp. 593–600.

Engineering Applications of Newton's Method of Approximation

By ROBERT W. RICHARDS

Structural Analytical Engineer,
The Budd Co., Philadelphia, Pa.

In computing deflections in diaphragms under various loading conditions, it is necessary to solve equations of the third degree. Solution by trial and error or by Cardan's Method of Substitution is so laborious and time-consuming that it is not convenient in cases where large numbers of equations must be solved. A more satisfactory procedure is to use Newton's Method of Approximation which in theory has been known for centuries but which in practice has been too often neglected. Newton's method provides a simple, rapid means for solving general equations of the nth degree with sufficient accuracy for the most exacting engineering analysis.

In mathematical terminology, Newton's method may be tersely stated. If $f(x)=0$ within the limits b and c such that $f(b)$ and $f(c)$ have opposite signs, and if between b and c, $f'(x)$ and $f''(x)$ are continuous and $\neq 0$, then between b and c, $f(x)$ has but one real root β which may be determined to any degree of accuracy by Newton's method. Because of the conditions which are requisite for the application of Newton's method, $f(x)$ must plot like the curves shown in Fig. 1 or 2 or like those symmetrical with them about the Ox axis.

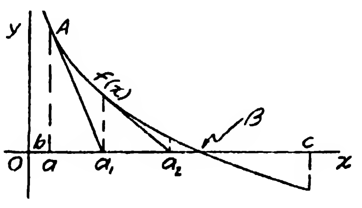


FIG. 1

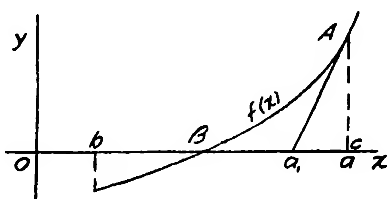


FIG. 2

Referring to Figs. 1 and 2, the equation of tangent at A is

$$\frac{y-f(a)}{x-a}=f'(a) \text{ or } y-f(a)=f'(a)(x-a).$$

a_1 may be found by setting $y=0$;

$$x=a_1=a-\frac{f(a)}{f'(a)}.$$

Then using a_1 as we have just used a, we get a closer approximation a_2 so that

$$a_2=a_1-\frac{f(a_1)}{f'(a_1)}.$$

As n increases, a_n approaches β.

The utility and versatility of Newton's Method can best be illustrated by a few practical applications.

In calculating diaphragm stresses, *i.e.*, tensile stresses resulting from flexure and direct tension (which occur when the deflection of a thin plate exceeds about one half its thickness), it is necessary first to determine the deflection y. For the particular case of a circular plate uniformly loaded with edges simply supported, y must be obtained from the following expression:

$$\frac{wa^4}{Et^4}=\frac{64}{63(1-v)}\left(\frac{y}{t}\right)+0.376\left(\frac{y}{t}\right)^3,$$

where w = Uniform load in pounds per square inch,
a = Radius of plate,
t = Thickness of plate,
E = Modulus of elasticity in pounds per square inch,
v = Poisson's ratio,
y = Maximum deflection.

If w, a, E, t, and v are known, this equation can be reduced to the form

$$my^3+ny+k=0.$$

Consider the following specific equation:

$$f(y)=13.56y^3+0.643y-.0115=0.$$

Then

$$f'(y)=40.68y^2+0.643.$$

As a first approximation of root, let $y=.05$;

$$\therefore\ f(y)=.1694\times10^{-2}+3.215\times10^{-2}-5.82\times10^{-2},$$

$$f(y)=-.0244,$$

$$f'(y)=.1017+0.643=0.745.$$

A closer value of the root is y_1:

$$y_1=y-\frac{f(y)}{f'(y)}=.05+\frac{.0244}{.745}=.05+.0314;$$

$$\therefore\ y_1=.0814.$$

Applying Newton's Method again to obtain a more accurate value of the root y_2,

$$f(y_1)=.732\times10^{-2}+5.23\times10^{-2}-5.82\times10^{-2},$$

$$f(y_1)=.0014,$$

$$f'(y_1)=.269+.643=.912,$$

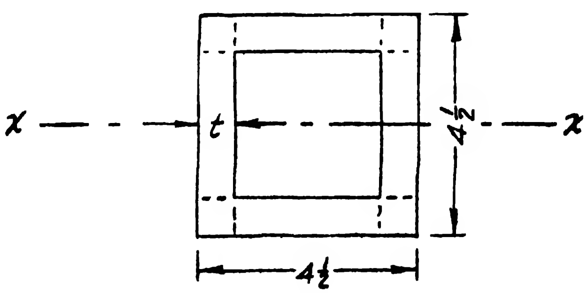
$$y_2=y_1-\frac{f(y_1)}{f'(y_1)},$$

$$y_2=.0814-\frac{.0014}{.912}=.0799.$$

This value of the root, obtained from only two applications of Newton's method, satisfies the original equation to three significant figures.

Once the deflection of the thin plate has been computed, the diaphragm stress may be readily obtained from a quadratic equation.

Newton's method may also be used to advantage in determining the thick-



ness of a hollow rectangular beam with given outside dimensions to satisfy a required moment of inertia.

For the section shown, the moment of inertia about the $x-x$ axis may be stated as a function of the wall thickness t, neglecting the corners.

$$I = -2.33t^4 + 20.25t^3 - 72.4t^2 + 60.74t = 3.9,$$

where 3.9 is the required value of I;

$$\therefore\ f(t) = -2.33t^4 + 20.25t^3 - 72.4t^2 + 60.74t - 3.9$$

and

$$f'(t) = -9.32t^3 + 60.75t^2 - 144.8t + 60.74.$$

Try 0.1 as a first approximation of the root:

$$f(.1) = -.000233 + .02025 - .724 + 6.074 - 3.9;$$

$$\therefore\ f(.1) = 1.47,$$

$$f'(.1) = -.00932 + .6075 - 14.48 + 60.74,$$

$$f'(.1) = 46.86;$$

$$\therefore\ t_1 = .1 - \frac{1.47}{46.86} = .1 - .0312 = .07.$$

Applying Newton's method again,

$$f(.07) = +.007 - .355 + 4.252 - 3.9;$$

$$\therefore\ f(.07) = .004,$$

$$f'(.07) = +.298 - 10.136 + 60.74,$$

$$f'(.07) = 50.90;$$

$$\therefore\ t_2 = t_1 - \frac{f(t_1)}{f'(t_1)} = .07 - \frac{.004}{50.9} = .0700.$$

Another convenient application of this method is to be found in calculating the nth root of an irrational number with the aid of a computing machine. To find the nth root of p, we must solve

$$f(x) = x^n - p = 0.$$

Then

$$f'(x) = n(x)^{n-1}.$$

As a first approximation, try a,

$$f(a) = a^n - p,$$

$$f'(a) = n(a)^{n-1}.$$

Then a_1, an improved value of the root, will equal

$$a - \frac{f(a)}{f'(a)},$$

$$a_1 = a - \frac{a^n - p}{na^{n-1}},$$

$$a_1 = \frac{1}{n}\left(an - \frac{a^n}{a^{n-1}} + \frac{p}{a^{n-1}}\right),$$

$$a_1 = \frac{1}{n}\left(an - a + \frac{p}{a^{n-1}}\right),$$

$$a_1 = \frac{1}{n}\left[(n-1)a + \frac{p}{a^{n-1}}\right],$$

where a = An approximate root,
a_1 = An improved value of root,
p = Any irrational number,
n = Required root.

For example, to find the cube root of 10, try 2.15 as a first approximation. This value was obtained from a slide rule which can be used to advantage in estimating square and cube roots. However, a less accurate value of the root could have been selected.

Therefore

$$p = 10,$$

$$n = 3,$$

$$a = 2.15,$$

$$a_1 = \frac{1}{n}\left[(n-1)a + \frac{p}{a^{n-1}}\right],$$

$$a_1 = \frac{1}{3}\left[2 \times 2.15 + \frac{10}{2.15^2}\right],$$

$$a_1 = \frac{1}{3}\left(4.30 + \frac{10}{4.6225}\right),$$

$$a_1 = \frac{1}{3}(4.30 + 2.16333) = \frac{1}{3}(6.46333),$$

$$a_1 = 2.1544.$$

Checking

$$a_1^3 = 2.1544^3 = 9.9995.$$

Thus with only one application of Newton's method, an accurate root was found. This method is practical when a computing machine is available to check solutions by logarithms or to give greater accuracy than the number of places in the tabulated logs.

Other functions such as those involving e^x can be readily solved by Newton's Method of Approximation. However, enough examples have been given to show the 20th century usefulness of this 17th century discovery.

REFERENCES

Fine, J. B. "Calculus"—John Wiley & Sons.
Roark, R. J. "Formulas for Stress and Strain"—McGraw-Hill Book Company.

Panel Discussion on Laboratory for Mechanical Engineers, Advanced Mechanical Engineering Laboratories

By JAMES J RYAN
University of Minnesota

Introduction

Laboratories for engineering students include studies of tests of materials, usage of chemical equipment, studies of fundamental principles in physics, and the functions and operations of machinery such as steam, internal combustion, refrigeration and other types of engines and shop machinery and machining techniques. In the Junior Mechanical Engineering Laboratories, various fundamental tests include measurements of oils, operation of engines, fundamental applications of control equipment and operation and study of basic machines utilized in steam, water and gas power production.

It has occurred to me that many of the basic principles involved in this earlier study of unrelated characteristics may be combined in more advanced laboratories in such a way that these principles may be subconsciously reviewed and more thoroughly understood. The application to unique combinations of equipment and their functions gives a meaning to the fundamental principles as determined by the projection of the individual into the development of the more advanced tests. An advanced laboratory of this nature would not only include earlier laboratory functions but would also review basic mechanics, physics, and many of the principles taught in the earlier courses where there has been less direct correlation with their application. An attempt to include generally the review and reevaluation of basic courses has been invoked in the development of the Machine Design Laboratory at the University of Minnesota, which may be used here as an example. In this laboratory specific fields of advanced machine design analysis of a complex nature have been set up to develop and accentuate ability of the student to utilize previous training in classroom or laboratory form in the solution and determination of factors which result in the more complex utilization of equipment. In the following discussion: (1) various types of laboratory problems will be briefly presented, leading to the correlation and advancement of previously obtained knowledge, and (2) general comments will be made with respect to this approach to engineering training.

I. Types of Advanced Larboratory Problems

A. Theory of Lubrication

The study of lubrication is sufficiently broad to warrant consideration by all Mechanical En-

gineering students. The hydrodynamic theory of lubrication is considered in the design of bearings and is given thought in the operation of all moving equipment in the various laboratories. Such a study involves the review of advanced mathematics, dynamics, hydrodynamics, and physics of fluids, applications of the study of the characteristics of lubricants, and the general design problems encountered in the operation of journals and bearings.

In the laboratories, a large shaft loaded with partial bearings on the top and bottom allows a brief study of the characteristics of speed, pressure, temperature, viscosity, clearances, power requirements, surface conditions, materials of shaft and bearing, methods of measuring temperatures, quantities of flow of lubricant and any other factors to be considered in the application of the hydrodynamic theory of lubrication.

Theory of Vibration.

A study of vibration characteristics opens a very broad field for fundamental analysis. Vibration in machines may be eliminated by proper design, by balancing procedures, by analysis with instruments, and by modification of the elements after construction. Conditions of vibration may be studied by the use of models, by tests with balancing machines, by a study of machine functions through analysis of noise with respect to frequencies and amplitudes, and by use of vibration instruments of recording and indicating types.

Familiarity of a student with this equipment and a study of the characteristics exhibited by these machines and instruments require a review of mathematical equations, theories of statics and dynamics, application of balancing weights, measurement of stresses, frequencies and amplitudes, and bring the student into contact with the practical aspects of the experiences he may entertain in the field of engineering, either by direct contact or association.

C *Theory of Photoelasticity*

The study of stress analysis by photoelasticity makes possible a physical picture of the internal mechanism of stresses and an opportunity to view and understand the stress phenomena which he has previously observed in textbook, lecture, and laboratory form. The photoelastic polariscope breaks up polarized light into two components which are changed in velocity by stresses in such a way that interference bands indicate stress distribution in doubly-refracting materials. Thus, an application of the theory of optics is given, the effects of wave lengths with respect to color in light, the opportunity for developing laboratory technique of the operator, the necessity for perfect alignment of the lenses and prisms, the use of filters, and various light sources, the study of complex stresses and their analysis by mathematical equations and the final presentation in the form of an individual report, including an analysis of data, graphs, and conlusions obtained presents a very broad application of much of the required knowledge with many application procedures on the part of the student.

II. General Comments on Laboratory Problems

A. Equipment

The type of equipment for Advanced Engineering Laboratory suggested here is preferably not a finished machine with commercial controls and completely enclosed elements. It is funadmental in nature, basic in construction, and modified for ease of attachment of measuring instruments, and indicating devices. This equipment is not established for any particular course or research problem, but should harbor a number of fundamental elements which may be rapidly visualized and understood In the preceding part, the discussion of lubrication, vibration, and photoelasticity equipment includes part of a set of laboratory experiments which consume approximately ten hours of lecture and thirty hours of laboratory. In a similar manner, it is suggested that broad fields in the division of Mechanical Engineering may be considered which are capable of sufficiently complex analysis to warrant advanced study of fundamental elements.

B. Test and Calculations

The student participation in the use of this equipment involves a study of the functions and a setup of necessary tools and instruments to obtain the analysis he desires. Some improvising should be necessary in the assembling of the equipment and a choice of methods of operation and test should be obvious. Some students may wish to make a more complex system; others may be content to do the minimum work necessary. As the tests proceed, they should be of such a nature that check calculations can be prepared and it is desirable that the final results may be checked against theoretical calculations. It should be possible to complete work on an individual set of problems during the laboratory period. Aids such as setting up data sheets and indicating the specific information needed will enable the student to understand more quickly the outline of the project and guide him in obtaining the necessary data. Sketches and calculation sheets are required and the specific data and the answers are to be shown on the data sheet. Percentages of error in the final results and the reasons thereof may be requested of a student.

C. Student Response

It is believed that the more advanced projects which tax the student's ability to think and act are preferred in this type of laboratory. In this manner, his interest is very intense throughout the entire project. If his initiative and understanding indicate that additional steps and calculations will obtain a greater amount of knowledge from the experiment, a student will strive for this result. In the assembly and set-up of the equipment and test instruments, the student becomes familiar with the use of wrenches, screw-drivers, standard connections and other equipment, and participates in the actual operation and test of the equipment. He has a better understanding of laboratory techniques, and although his skill is

not greatly increased, he develops an evaluation of information obtained by tests, the activities and procedures necessary to operate tests, and considerable responsibility in the performance of tests.

Conclusions

What may be the central theme of this discussion is the fact that all Mechanical Engineering students should be allowed to participate in advanced laboratories with sufficient complexity and personal responsibility as part of their student training. It is particularly important that students be allowed the opportunity of having experience, under controlled direction, wherein they are required to think and act with independence and assurance. Incidentally, they learn what a sine curve is as applied to the machine and the physical application of the logarithmic damping function.

Thus, the Advanced Engineering Laboratory in Mechanical Engineering should be one in which the student has considerable freedom to understand and evaluate a great number of the fundamental ideas which have been supplied to him during his course work in engineering.

Training for Research*

By ERIC A WALKER

The Pennsylvania State College

The most obvious reasons for training engineers for positions in research are that there is an acute demand for engineers and scientists with such training and that a good fraction of our better students wish to acquire such training while still in school. This is not new, and there has been a growing trend in this direction for years. A recent study[1,2] shows that about 6 per cent of the electrical engineers who are from fifteen to twenty years out of college are now engaged in research. This is not a large percentage of the whole. However, one out of five electrical engineers in the same age group is engaged in administrative activities. Undoubtedly some of these men graduated to such positions from careers in research and development. There are many other engineers who are classified as development engineers who might well be called research engineers. The same study shows that about 9 per cent of the same age group can be placed in this classification.

The trend toward research and development is growing, and it might be safe to estimate that one out of five of our electrical engineering graduates becomes a research engineer or scientist for part of his useful life. The line of demarcation is not a hard-and-fast one. Many development engineers and design engineers spend an appreciable fraction of their time on research. Every such engineer has found that when he starts to pioneer or even to create a design a little out of the ordinary, he is confronted with a lack of fundamental knowledge which must be obtained before the design can continue in an orderly and logical manner. He therefore has to stop his design engineering and indulge in a little applied research and thus, for the time being at least, he becomes a research engineer. Actually, the number of engineers who today are going into research is much greater than it has been in the past. Consider Table I, which gives some study of the growth of the number of research institutions, the number of research scientists, and the amount of money spent on research. In this table the national income is given as a baseline against which the dollar value of research should be measured. It is probably true that the money spent on research reached a peak during the war years. This situation was forced by the rapid development of government agencies interested in research, such as the Office of Scientific Research and Development, the National Defense Research Committee, etc.

* Presented at the Educational Methods Section, A.S.E.E., Minneapolis, June 18–21, 1947.

[1] "Employment Histories of Engineering Graduates," E. D. Howe, *Journal of Engineering Education*, Vol. 37, No. 7, p. 513.

[2] "A Re-examination of the Compton Report," H. H. Armsby, *Journal of Engineering Education*, Vol. 37, No. 9, p. 675.

TABLE I

Year	Number of Industrial Research Laboratories	National Income $	Funds for Industrial Research $	Funds for Government Research $
1920	300	74.10^9	29.10^6	15.10^6
1930	—	77.10^9	116.10^6	24.10^6
1940	2200	77.10^9	234.10^6	69.10^6
1944	2500	160.10^9	300.10^6(?)	719.10^6

Undoubtedly we are now in a period when many of the research scientists are returning to their pre-war jobs in teaching, production, and even in fundamental scientific work. There will be another reduction in the number of research engineers when the country's economic system falters once again and we have an economic depression Nevertheless, the relative growth of research is permanent. No longer is research confined to the few large companies which can afford such a luxury, but research has become a necessity for the smaller companies which wish to insure their economic survival. It is true that research is not understood by many of those who feel it is a necessity, but it has become as necessary as insurance, and company A must have some research if only because its competitors have it and its competitors seem to do all right.

Since it is an established fact that the number of scientists engaged in research is rapidly growing, one might examine the engineer's place in this growth to determine if an engineering training is satisfactory for a career in research. There is considerable evidence that such training is not as good as it should be. This quality is not easy to measure, but some arbitrary yardsticks can be chosen. For instance, one might make a count of a number of scientists engaged in research and development and then determine what percentage was trained as engineers. As an example, if one lists the men who are prominent in the National Defense Research Council and defines *prominent* by saying they were listed as members of the division committees, one finds in a group of eighty-six such men thirty-six physicists and only seventeen engineers. Of this latter number, nine were electrical engineers, and the remainder were scattered among other branches.

Another measure might be the number of scientists employed by the directors of war research laboratories. Again it can be shown that a much larger percentage of these are physicists than engineers. One laboratory in particular hired five men trained as physicists for every one trained as an engineer.[8] As a matter of fact, at least one scientist went on record as saying that he favored the hiring of physicists because "the physicists showed more imagination."

Whether or not this rather offhand analysis is defensible is beside the point, but many laboratory administrators will admit that the physicists not only showed more imagination but had a wider knowledge. They knew more ways of filling a given need than did the engineers, and their analytical ability in many cases was quite superior. Lastly, because they had never learned any design formulas or knew anything

[8] "Roster of All Employees, Underwater Sound Laboratory, Harvard University, 1941-1946."

of the traditions behind standard designs, they were less inhibited and, although their mistakes were many, their successes were many and startling. These are facts, and using them as a basis, we might re-examine the qualifications of a good research scientist and see if our engineers can fill the specifications. If they do not, we might see how we can modify our training so that they do.

Some of the requirements for a research scientist are quite easy to list, although one might have difficulty in arranging them in order of their importance.

First, a scientist must have an analytical and inquiring mind. He must want to know what makes things tick and must want to understand the fundamental laws governing the action of any system or physical phenomenon.

Second, he must have considerable facility with mathematical principles and reasoning. He should want to explain the physical laws in terms of simple mathematical symbols which clearly and concisely contain all the facts necessary to predict the behavior of a system under different circumstances.

Third, he must be familiar with the ordinary physical concepts and the reasoning behind them. For instance, there should be no ambiguity in the scientist's mind when one tries to discuss with him an electric field consisting of flux lines and equipotentials. He should be able to visualize the mechanical considerations which govern the period of vibration of an oscillating system and should clearly understand those properties which can change the vibration characteristics.

Fourth, he must be familiar with the experimental method. This means he should have a certain amount of manual dexterity so he can set up apparatus with which to make fundamental measurements; but more important than merely making the measurements, he must be capable of posing the crucial question. By this we mean he must be able to state his theory so that it can be tested and proved valid by a set of physical measurements.

Fifth, it goes almost without saying that a scientist must have the intellectual integrity to lean completely and impartially on the data. He must not allow himself, by wishful thinking, to interpret the data in any dubious manner and thus lead himself astray and prove correct theories which are dubious or definitely false.[4]

Lastly in this brief analysis, the scientist must have the ability to express himself. There are three ways of doing this: by graphs and drawings, by mathematical symbols, and by expository writing. Obviously, it is of little avail for a scientist to arrive at a new theory if he cannot explain it to his colleagues and to the development and design engineers who must ultimately translate the theory into mechanisms for the public good.

In summary, then, the scientist or research engineer must have an inquiring mind; must be capable of handling mathematical and physical concepts; must be familiar with the experimental method; and must be capable of expressing himself.

If our regular four-year college course is not properly training engineers to become research scientists, we

[4] In an excellent paper entitled "Selection and Training of Students for Industrial Research," Dr. A. W. Hull lists the following characteristics: (1) character, (2) aptitude, (3) attitude, (4) knowledge. Of these Dr. Hull contends that character is the most important, and under character he lists *positive* honesty as absolutely essential. Cf. A. W. Hull, *Science*, Vol. 101, No. 2616, p. 157.

should try to ascertain the reasons and make the proper corrections. The first impulse is to attack the curriculum and to suggest the addition of new and different courses. Many will say the curriculum itself should be extended to five, six, or even seven years. However, leaving this argument aside, we might examine the matter to see if things can be improved without extending the allotted time.

First of all, do we know if our selection of students as embryo engineers or research scientists is good? Obviously, this must have something to do with the matter, for when a student comes to us, he has had eighteen years of training and has certain traits and capacities which he has inherited. Some measure of his ability to become a researcher should be found. This is doubly difficult, since although we are able to enumerate, in qualitative manner, those qualities which are sought in a scientist, we are not certain that these are the qualities which make a scientist a good one. If they are, we have no way of measuring them except by observing those scientists who have proved successful. Therefore, it seems that one of the first things we must do is to find some measure of a good scientist and then test our students to see if they have this scientific aptitude. This is a two-prong program which cannot be accomplished in a short time, but it is a program which well might be taken under advisement by the Committee on Educational Methods. Only after accomplishing this initial step will we be in a position to examine fruitfully our teaching and curricula.

There is always an urge to add certain specific courses to remedy specific ills; yet one must remember that good research engineers are trained in all of the curricula: aeronautical, mechanical, electrical, and chemical engineering. It seems fairly obvious that it is not so much the specific training that one receives as the type and breadth of training. To insure the necessary breadth, courses must be added which are not in the specific science covered by a certain specific curriculum. Many electrical engineers are quite deficient in thermodynamics and should have more thorough grounding in that science. The study of thermodynamics is not to be confused with the study of power plants or internal combustion engines, but it should emphasize the theoretical bases of that science. In a similar manner, the electrical engineer usually needs more aero- and hydromechanics. It is true that many electrical engineering courses include a course in hydraulics, while in others the course is omitted because most such courses are limited to the study of empirical formulas on weirs and simple static analyses. With such treatment, the course falls into ill repute and eventually is removed from the curriculum in disgrace.

The same sort of analysis may apply to curricula in other branches of engineering. Unfortunately, all such remedies presuppose the addition of material to the already overcrowded calendar, and therefore one must seek to remove courses to save time and to improve the overall efficiency. Again only loose generalities can be offered. One must remove all material which has transitory value only and concentrate on the enduring truths of science. The descriptive courses which tend to explain how a gadget works and how it is made can readily be scrapped and should be, since that gadget may not exist ten years from now, and if it does, it certainly will not be made in the same way. The "how-to-do-it" courses

and courses in manual arts will have to be eliminated, for valuable as such skills are, they must be relegated to the position of other self-taught attainments

The most urgent need in the training of a research scientist is a broad understanding of physical phenomena. This cannot be filled by a prescribed course or curriculum, and only the teacher who himself possesses a broad understanding can effectively aid the student. A teacher who has such an understanding can point out the similarity between one set of physical phenomena and another, and the likenesses between the methods by which similar problems are solved. For instance, in the study of electrostatic fields, we arrive at equations for equipotentials and flow lines by a solution of the so-called equation of Laplace. This same equation holds for fluid flow, and its solution is equally valid for stream lines and pressure contours. Similar equations and solutions are found for vibrating systems in mechanics and for electrical oscillations in circuits. Acoustical impedance is very similar to electrical impedance. All these concepts may be emphasized to aid the student in obtaining a thorough understanding.

There are many other things which can be done to help train our engineers for positions in research and development. Each of us can think of items which might be useful, such as an undergraduate thesis, more mathematics, courses in instrumentation, courses in report writing, etc. However, these suggestions, like all others, rest on personal opinion. As said previously, the one important thing is that we do not actually know what training will make a good research engineer because we have never been able to make any measurements. We have never measured qualifications of a good scientist. What we, as teachers, need more than anything else is research on teaching and, in particular, research on training for research.

Conference on Administration of Research

A conference on the administration of research was held at the Pennsylvania State College, October 6 and 7, 1947. The conference was sponsored by the School of Engineering of the Pennsylvania State College. Two hundred leaders of research management from laboratories in the United States and Canada registered for the conference. Laboratories both large and small, managed by industry, educational institutions and governmental agencies were represented. The high level of ability, reputation and experience in research as represented by the registrants, as well as by those on the program, assured the success of this conference before it was opened.

Following registration, the Monday morning meeting was called to order by H. P. Hammond, Dean of the School of Engineering of the Pennsylvania State College, who, after a brief introductory talk, introduced J. A. Hutcheson, Associate Director of the Research Laboratories of Westinghouse Electric Corporation, as chairman of the Monday morning session. Speakers at this session were Maurice Holland, Industrial Research Adviser, New York City; R. L Jones, Vice President, Bell Telephone Laboratories; and G. H. Young, Assistant Director, Mellon Institute of Industrial Research.

Mr. Holland spoke on "The Place of Research in the Corporate Structure." The subject of the talk by Dr. Jones was "Organization by Scientific Division." This was followed by a paper "Organization by Individual Projects" by Dr. Young.

The meeting Monday afternoon was led by Philip M. Morse as chairman. Dr. Morse is the Director of Brookhaven National Laboratories. "Research Reports—Their Form and Usefulness" was the subject of a paper by Dwight E. Gray, Editor, Applied Physics Laboratory, Johns Hopkins University. L. W. Chubb, Director of the Research Laboratories of Westinghouse Electric Corporation, presented a paper "Inventions and Patent Policy." "Policy on Publications" was the subject of a talk by E. U. Condon, Director, National Bureau of Standards.

The dinner speaker at the meeting Monday evening was Col. Leslie E Simon, Director, Ballistic Research Laboratories, Aberdeen Proving Ground, who spoke on "German Research in World War II," based upon personal investigation of German research laboratories made since the war.

The chairman of the session Tuesday morning was J. E. Hobson, Director, Armour Research Foundation. The first paper on the program at this meeting was one by Commodore Henry A. Schade, Director, Naval Research Laboratory, on "Inception and Development of a Research Project." B. B. Wescott, Gulf Research and Development Company, presented a paper, "Analyses of Research Costs." P. D. Foote, Executive Vice-President, Gulf Research and Development Company, used Dr. Wescott's presentation as a basis for a further discussion of "Analyses of Research Costs." "Selection and Training of Research Personnel" was the subject of a paper by A. W. Hull, Assistant Director, Research Laboratories, General Electric Company.

Proceedings of this conference will be published as soon as possible. The price is $3. Copies may be obtained from Prof. Kenneth L. Holderman, Pennsylvania State College, State College, Pennsylvania.

Sections and Branches

The **Allegheny Section** met at State College, October 10, 1947, and the following officers were elected:

Chairman, W. A. Koehler, West Virginia University.

Vice Chairman, R. C. Gorham, University of Pittsburgh.

Secretary, D. T. Worrell, West Virginia University.

The **Kansas-Nebraska Section** held a meeting at the Kansas State College October 17–18, 1947, and elected the following officers:

Chairman, H. L. Daasch, University of Kansas.

Vice Chairman, J. S. Blackman, University of Nebraska.

Secretary-Treasurer, R. F. Morse, Kansas State College.

Representative on Council (2 years), L. E. Conrad, Kansas State College.

The **Missouri Section** has elected S. H. Van Wambeck, Washington University, St. Louis, Mo., as its representative on the General Council for two years.

The **New England Section** elected the following officers at its meeting at the University of Massachusetts, October 11:

Chairman, C. E. Tucker, Massachusetts Institute of Technology.

Secretary, W. E. Keith, New England Tel. & Tel. Co.

Representative on Council (2 years), W. C. White, Northeastern University.

The fall meeting of the **New England Section** of the Society was held at the University of Massachusetts, Amherst, on Saturday, October 11, 1947. The total registration was 307 members and guests.

The following conferences were held:

A. Chemical Engineering

Graduate Study in Chemical Engineering. Walter G. Whitman, Massachusetts Institute of Technology.

B. Civil Engineering

Construction Courses in an Undergraduate Civil Engineering Curriculum. John B. Babcock, Massachusetts Institute of Technology; C. Clark Macomber, Macomber Construction Company, Boston, Massachusetts.

C. Electrical Engineering

English a Neglected Engineering Tool. Donald B. Sinclair, General Radio Company, Cambridge, Massachusetts.

Communications. Lynwood S. Bryant, Massachusetts Institute of Technology.

D. Mechanical Engineering

Specifications for an Engineering Instructor. William H. Kenerson, Brown University; Paul Cloke, University of Maine.

E. Drawing

Secondary School Preparation for College Engineering Drawing. Chester L. Thorndike, Springfield Junior College and Technical High School.

College Graphics Re-examined. C. Harold Berry, Harvard University.

F. Engineering School Libraries

The Engineering Library in Engineering Teaching. Harold Hazen, Massachusetts Institute of Technology.

G. English and Humanities

Reaching the General Reader. Dudley H. Cloud, Managing Editor, *Atlantic Monthly*.

Contemporary Poetry for the Professional Student. John Ciardi, Harvard University.

The Columbia Humanities Program and the Professional Student. Kent Hieatt, Columbia University.

H. Mathematics

Mathematics and Modern Industry. Charles V. L. Smith, Raytheon Manufacturing Company, Waltham, Mass.

A Specification for the Quality Control Engineering Applicant. C. D. Ferris, General Electric Company, Bridgeport, Conn.

I. Mechanics, Strength of Materials, and Fluid Mechanics

What Is Ahead in the Teaching of Fluid Mechanics? Paul E. Hemke, Rensselaer Polytechnic Institute.

What Is Ahead in Strength of Materials Laboratory? Gleason H. MacCullough, Worcester Polytechnic Institute.

J. Physics

Cornell's Program in Engineering Physics. L. P. Smith.

Harvard University's Program in Engineering Sciences and Applied Physics. F. V. Hunt.

What Should the Engineering Student Bring from His Course in Physics? J. P. DenHartog, Massachusetts Institute of Technology; D. E. Howes, Worcester Polytechnic Institute; William P. Kimball, Dartmouth College.

A brief business meeting was held at 1:30 P.M. in Bowker Auditorium with Chairman Tucker presiding. The secretary commented upon the generous response of institutions in the Section to the request for a ten-dollar donation from each to cover printing costs of the News Bulletin and Program, mailing expenses, etc.

J. S. Thompson, Treasurer of the Society, was introduced and brought the greetings of the National Office to the Section. Chairman Tucker read a letter announcing the appointment of Arthur B. Bronwell of Northwestern University as Secretary to replace Dr. F. L. Bishop of the University of Pittsburgh who retired from the office after many years of service. Professor Higbie Young of Cooper Union, and Chairman of the Mid-Atlantic Section of A.S.E.E., spoke briefly and brought the greetings of his Section to the New England Section. Professor C. L. Dawes, the Section's Representative on the National Council, reported briefly upon the recent meeting in Minnesota.

The annual dinner was held at 6:30 P.M. in Greenough Hall with an attendance of 202. Chairman Tucker presided over a brief business meeting following the dinner. Dean L. E. Seeley of the University of New Hampshire, as Chairman of the Nominating Committee, presented the following nominations for officers of the Section for the ensuing year. For Chairman—Professor C. E. Tucker, for Secretary—Mr. W. E. Keith, for Section Representative on the National Council—Dean W. C. White. No additional nominations were presented and with President Dodge presiding

temporarily the nominated officers were elected.

The **North-Midwest Section** elected the following officer at its meeting at Marquette University, October 17–18, 1947:

Chairman, F. L. Partlo, Michigan College of M. & T.

T. C. Brown has been elected to serve as Chairman of the **North Carolina State College Branch,** W. N. Hicks is Vice Chairman.

College Notes

Northwestern Technological Institute. Philip C. Rutledge, Professor of Civil Engineering, was appointed chairman of the department this fall to fill the vacancy caused by Professor George Maney's death. Professor Rutledge has been on the faculty at Northwestern since 1943 and taught at Purdue previously.

New men on the faculty include William T. Brazelton, Instructor, and George Thodos, Assistant Professor of Chemical Engineering; James J. Cadwell, Assistant Professor of Civil Engineering; Messrs. E. Richard Owen and Richard L. Petritz, Instructors in Electrical Engineering, and Messrs. Richard H. Cole and Donald R. Diggs, Lecturer and Instructor in Mechanical Engineering, respectively.

A new nuclear chemistry laboratory is now being equipped by **Rensselaer Polytechnic Institute** to augment its nuclear science and engineering program. Facilities will be provided by the new laboratory for training and research in connection with the course in nuclear chemistry inaugurated by Rensselaer in September. This course is under the direction of H. M. Clark, Assistant Professor of Physical Chemistry.

Papers given last June in Minneapolis before the **Engineering College Research Council** and at the **Fifth** General Session of the Society have been published in the Proceedings of the Research Council. Copies are available from Mr. John I. Mattill, Secretary, at the State University of Iowa, for $1 each.

James S. Thompson, Treasurer of the A.S.E.E. and Executive Chairman of the Board, McGraw-Hill Book Company, has been appointed a representative of the Committee on International Relations of the **Engineers Joint Council** to attend a meeting of representatives of engineering groups of North and South America **at Lima,** Peru, to be held the end of November 1947. At the Lima meeting, plans will be made for the organization and the convening of a Pan-American Engineering Congress.

Men Trained in Welded Design are Essential

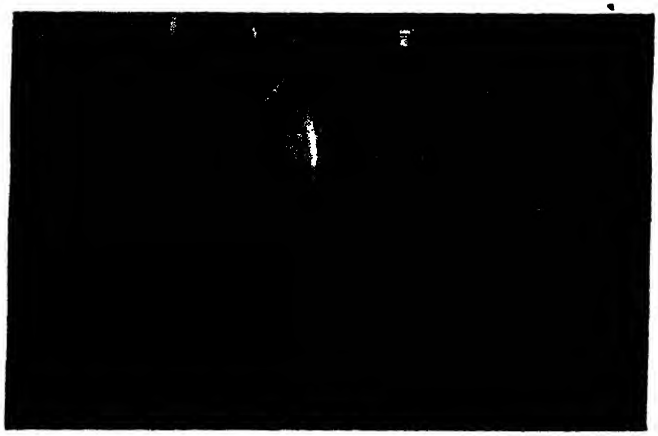
THE Globe Company is one of the oldest manufacturers of equipment for the meat packing industry. In our continuous program of improving our designs and production methods, we find it helpful to think in terms of arc welded steel construction. Welding gives us greater flexibility in our approach to designing problems. The result is equipment that is strong, rigid and light-weight, with smooth, sanitary surfaces.

Our work must be of high standard at all times, and the men who are being trained in the engineering colleges for welded design and production are becoming more essential to us every day.

Chas E Gamble

President
The Globe Company
Chicago, Illinois

This Globe Dry Rendering Cooker is of welded construction.



Published through the courtesy of The Lincoln Electric Company, Cleveland 1, Ohio

56th
Annual Meeting

American Society
for
Engineering Education

UNIVERSITY OF TEXAS

AUSTIN, TEXAS

June 14 - 18, 1948

THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION
OFFICERS 1947–48

President

Charles E. MacQuigg, The Ohio State University, Columbus 10, Ohio

Vice President, 2 years

(In charge of general and regional activities)

B. J. Robertson, University of Minnesota, Minneapolis, Minn.

Vice President, 1 year

(In charge of instructional division activities)

C. J. Freund, University of Detroit, Detroit, Mich.

Vice President, 2 years

(Engineering College Administrative Council)

S. S. Steinberg, University of Maryland, College Park, Md.

Vice President, 1 year

(Engineering College Research Council)

F. M. Dawson, State University of Iowa, Iowa City, Iowa

Secretary

Arthur B. Bronwell, Northwestern University, Evanston, Ill.

Treasurer

J. S. Thompson, McGraw-Hill Book Co., New York 18, N. Y.

Assistant Secretary

Nell McKenry, Northwestern University, Evanston, Ill.

Headquarters

Northwestern University, Evanston, Ill.

56th Annual Meeting

Austin, Texas, June 14–18, 1948

Host

University of Texas

Other WILEY books on page 7

Other WILEY books on page 6

The Society—A National Forum

By ARTHUR BRONWELL

Secretary of the Society

A survey of the progress of engineering education over the past quarter of a century reveals the vigorous and constructive efforts which members of the A.S.E.E. and its predecessor, the S.P.E.E., have contributed to the advancement of engineering education. Against a kaleidoscopic background, stand out a few clearly defined, monumental contributions which have elevated the profession to a new high point of surveilance, making it possible to obtain a deeper understanding and a greater appreciation of the responsibilities and long-range goals of engineering education.

However, the most significant contributions of the Society are to be found not in the eminent masterpieces, but rather in the functioning of the Society in its capacity as a national forum for the interchange of ideas and the inspiration and stimulus which this has brought to bear upon the manifold problems of engineering education. Every conceivable phase of engineering education has been subjected to critical and constructive analysis through the medium of the Society's meetings, its publications, and through the activities of its councils, committees, divisions, sections, and branches. Out of the cauldron of the past has come a more or less clearly defined plan of engineering eudcation and a sturdy foundation has been laid.

At times, we may feel intuitively that the basic foundation and the framework of our system of engineering education have been so thoroughly planned that little improvement is necessary and we need now concern ourselves only with adding to the superstructure according to the well-defined plans of our predecessors. We may be lured to the conclusion that engineering and the basic sciences have evolved to a quiescent plateau from which there will be continued progress, to be sure, but that the basic pattern of engineering education will remain fixed and immutable; that the task of the future is merely one of improvement and refinement. Even the social sciences and the humanities, those long-neglected segments of engineering education, have been subjected to critical analysis and a solid foundation has been laid for correcting the deficiencies of the past.

What new challenges lie ahead? Can we safely say that the major problems of engineering education have all been solved; that we can now close the books to progress; that we can follow the example of Rip Van Winkle and take a long sleep? If such an attitude had been adopted by the Society and its members a quarter of a century ago, the tragedy of it would be apparent today. No one would deny that there has been a complete reformation

in our whole structure of engineering education during the past quarter of a century—a reformation which was vitally necessary in order that education keep pace with the rapidly expanding frontiers of science and technology.

It is equally apparent that scientific and technological progress today is expanding at a more rapid rate than ever before in the history of mankind. This accelerated progress may be attributed to the unprecedentedly large number of highly trained scientists and engineers, as well as to the increased emphasis placed upon research by the colleges, industry, and government. There can be little doubt that the resulting expansion of scientific and technological knowledge will profoundly alter the engineering curricula of the future. During the past quarter of a century we have seen whole new areas of science and engineering invade the curricula and take a permanent part in our engineering education. In view of the rapid strides of science and engineering today, it is reasonable to assume that the engineering curriculum twenty-five years hence will be as different from that of today as today's curriculum is from that of a quarter of a century ago.

The A.S.E.E. must continue to serve as a national forum for the exchange of ideas. It must continue to serve as a unifying agency through which the members of the Society can exert their constructive influence for the advancement of engineering education. Progress often is marked by two steps forward and one step backward. To assure continued progress in the right direction requires first, a clear definition of the major issues, then a logical, orderly approach to the solution of the problems. It requires discriminating judgment with a cautious observance of the long-range objectives. It requires the efforts, the abilities, and the inspiration of all of those who recognize a keen sense of obligation toward their profession.

Texas Awaits You

A typical Texas "Howdy" and a warm handclasp await members of the American Society for Engineering Education attending the Society's 1948 annual meeting at the University of Texas next June (14–18).

Located in Central Texas in the capital city, Austin, the University is the capstone of the Lone Star State's educational system. Opened in 1883, it is the largest educational institution south of Chicago and east of California.

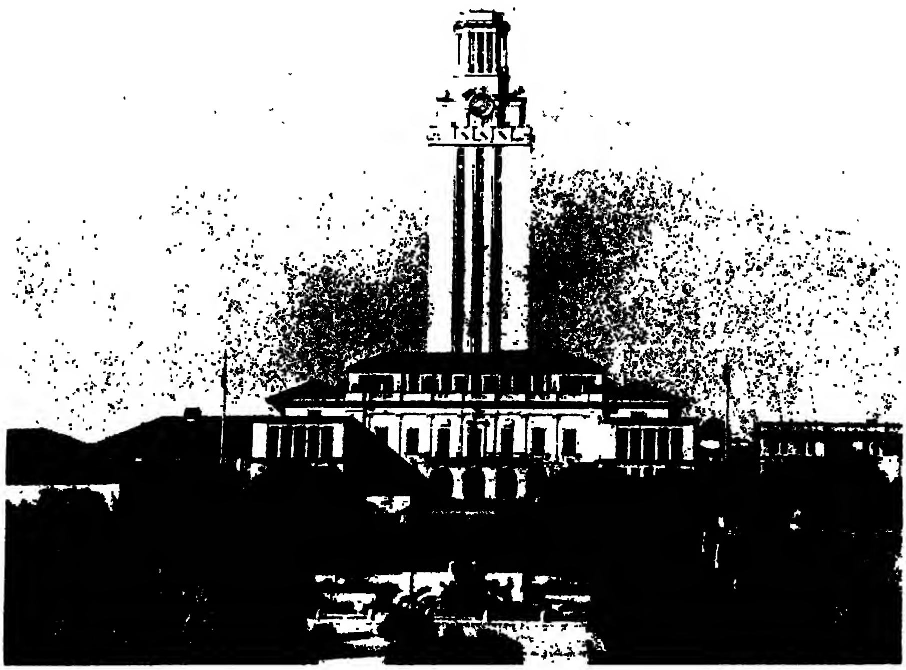
Its College of Engineering was created in 1894 Engineering registration for the current semester is 3,681 students out of a total of 17,343 and is surpassed only by Colleges of Arts and Sciences registration among eight colleges and schools of the Main Campus. Well over 3,000 engineering degrees have been conferred since 1894.

Although the central seat of the University is the Main Campus in Austin its education, research and services spread well over Texas' 263,644 square miles. Its Medical Branch is in Galveston. The Dental School and the University owned M. D. Anderson Hospital for Cancer Research are in Houston. The College of Mines and Metallurgy is in El Paso. It owns and operates cooperatively with the University of Chicago, the W. J. McDonald Observatory in the Davis Mountains of far West Texas. Constitutionally, the Agricultural and Mechanical College of Texas, in College Station, is a sister institution, although governed by a separate board of directors.

The Main Campus covers 200 acres in the heart of Austin. The 27-story Library-Administration tower competes

ENGINEERING BUILDING, UNIVERSITY OF TEXAS

Campus View, University of Texas, Tower of Library-Administration Building in Background



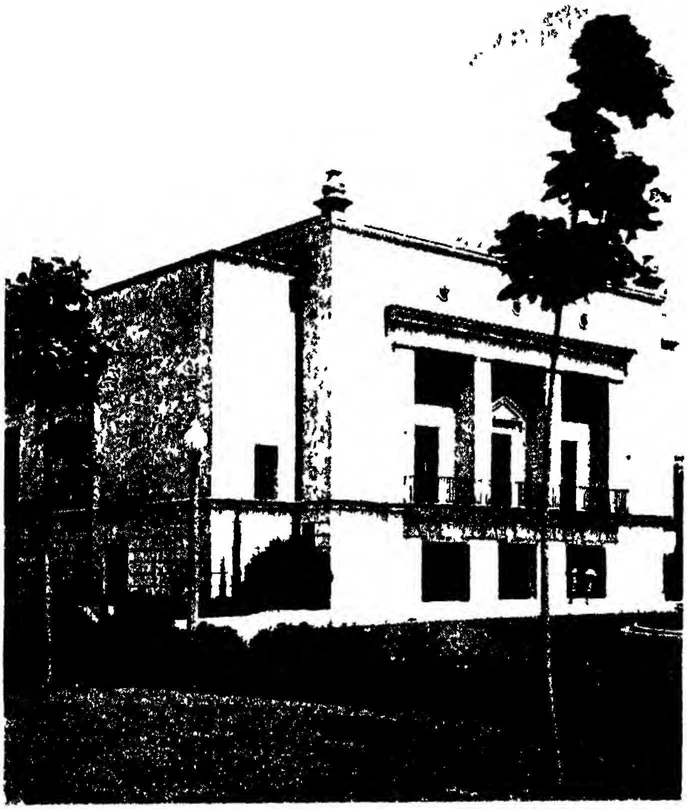
Administration-Library Building, University of Texas

with the capitol dome in dominating the city. More than 50 buildings are spread about the Main Campus.

Last year there were 1,023 teachers on the staff, including 835 full-time positions. Approximately 100 full-time positions have been added this year.

The faculty includes many prominent educators and scientists. Administrative head of the University is Dr Theophilus S. Painter, eminent geneticist and member of the National Academy of Sciences. He was the 1934 winner of the Academy's gold medal as the nation's outstanding scientist. He left the laboratory in 1944 to become acting president and was appointed president in May, 1946. He has been a member of the faculty since 1916. Dr. Painter received his A.B. degree from Roanoke College; his A.M. from Yale and his Ph.D. from Yale. He was awarded an honorary doctorate of science by Yale in 1936. Before coming to the University of Texas he was an instructor in biology at the Sheffield Scientific School.

The University's influence is felt far beyond the borders of its campuses. Through its Extension Division it operates probably the largest program of interscholastic literary, mathematics, music and sports competition in the na-



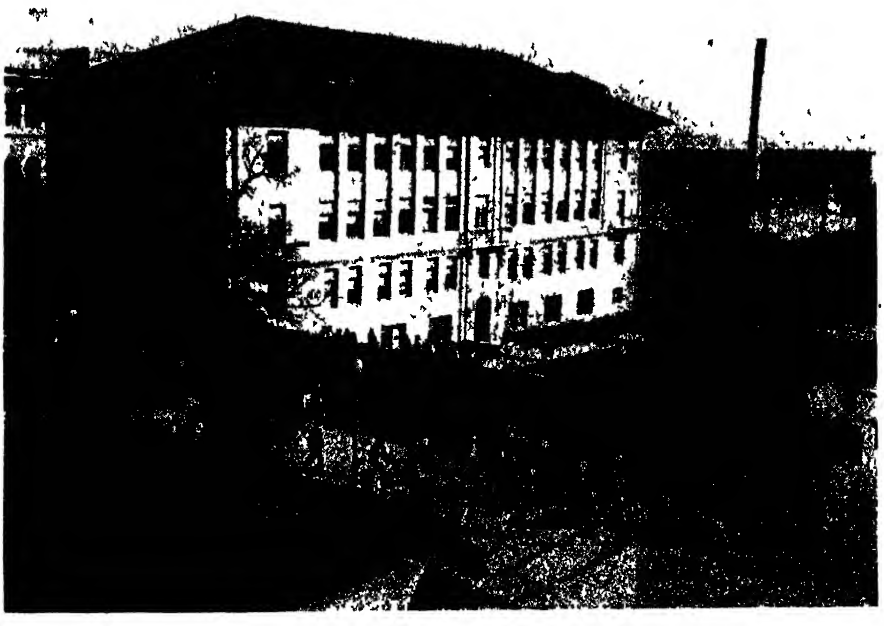
Hogg Memorial Auditorium, University of Texas

tion The division also maintains teaching, industrial and business, library and visual instruction bureaus

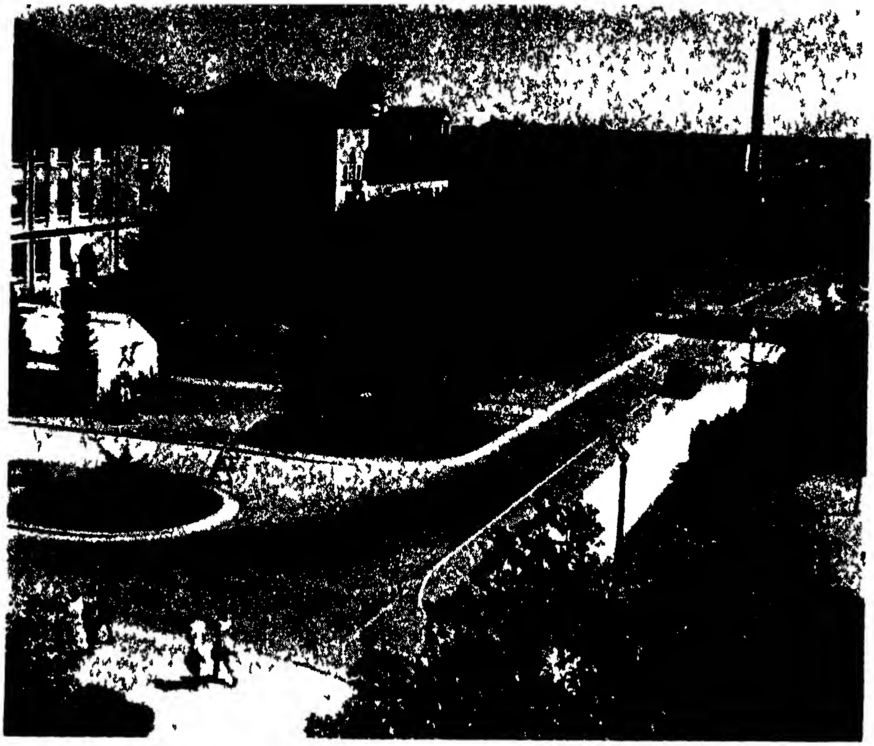
More than 20 organized University research bureaus and institutes serve the state and nation through publications and otherwise It operates a statewide mental hygiene program and a child health program which are financed by foundations Radio House, a workshop-laboratory, originates entertainment and educational programs for many types of audiences

In sports it is a leader in the Southwest Conference and its varsity teams usually are at home among the nation's best

Financially it is unique More than 1,000 oil wells contribute to its support and development. The constitution of 1876 set aside a million acres of West Texas land and later the Legislature added a second million acres for a permanent university fund. The land, once thought to be of value only for grazing purposes, later proved to contain oil bearing sands The income from oil lease sales, royalty and lease rentals goes into the permanent fund The permanent fund is invested. The income from the investments is divided approximately two-thirds to the University and one-third to Texas A & M College Although the income is increasing the University remains dependent upon legislative appropriations for a large portion of its operating income Income from the permanent fund is earmarked principally for building and a large expansion program is now being planned The present plant was designed for a maximum of 8,000 to 10,000 students and postwar enrollment increase has overtaxed it tre-



Campus Scene With Geology Building in Background, University of Texas



CAMPUS SCENE UNIVERSITY OF TEXAS BUILDINGS, LEFT TO RIGHT BIOLOGY, PHYSICS CHEMISTRY AND ENGINEERING

mendously Temporary dormitories and classroom buildings have been helpful but have not solved the problem of overcrowding

Veterans account for the large post-war enrollment increase, there being 10,577 enrolled for the current semester The trend of non-veteran enrollment is upward and may continue until about 1960

The University's story is a long one, with a thousand ramifications It includes legends, traditions, political strife. It also includes hospitality and members of the American Society for Engineering Education are urged to sample it to the fullest next June

Summer's sometimes intense heat has not usually arrived by mid-June Balmy days and cool nights should be in order Recreation opportunities will be plentiful Swimming, boating and fishing are abundantly available within the city limits and in the artificial lakes of the Lower Colorado River Authority system which form a chain running northwesterly from Austin Plane, train, bus and automobile place Houston, San Antonio and Dallas within easy reach The Gulf Coast is a few hours distant and Mexico's nearest port of entry, Nuevo Laredo, opposite Laredo, Texas, is 250 miles by highway

Evening Graduate Programs in Electrical Engineering*

By FRNST WEBER

Head, Department of Electrical Engineering, Polytechnic Institute of Brooklyn

Evening graduate programs have been successful in several metropolitan centers of population which are also centers of industry. Though individual graduate courses had been offered in late afternoon or evening since about 1920, complete degree programs on the Master's level were first introduced at Polytechnic Institute of Brooklyn in 1925 in Chemistry, and in 1928 in Electrical Engineering. The first complete doctoral evening program in Electrical Engineering in the country was offered in 1936 at the Polytechnic Institute of Brooklyn.

According to the latest available statistics published in the January, 1947 issue of the JOURNAL OF ENGINEERING EDUCATION, the enrollment figures for the graduate programs in Electrical Engineering were as follows:

STUDENIS IN E.E. MASTER'S PROGRAMS

	FULL TIME	PART TIME	TOTAL
for the Nation	1189	1474	2663
for Polvtechnic Inst. of Brooklyn	46 (3.9%)	209 (14.2%)	255 (9.6%)

STUDENTS IN E.E. DOCTORAL PROGRAMS

	FULL TIME	PART TIME	TOTAL
for the Nation	69	93	162
for Polytechnic Inst. of Brooklyn	3 (4.4%)	41 (44.2%)	44 (27.2%)

Quite different from the situation in the undergraduate programs, we find more students pursuing part time and evening graduate studies than are enrolled in full time graduate work! That a large proportion of the former is found at our Institute is, among other factors, attributable to its location in the heart of the greatest metropolis which is also the focal point of some of the most important research and development laboratories in Electrical Engineering.

This enormous growth of evening graduate programs raises at once the questions of why they were successful and how they might compare with day graduate programs.

It has been the experience that evening graduate courses serve *two purposes*. They either give specialized information in fields of particular interest to men employed in research and development laboratories; or they make possible a combination of gainful employment and study on the graduate level for advanced degrees. Nor-

* Presented at the annual meeting of the A.S.E.E., Minneapolis, June 18–21, 1947.

mally, enrollment at the Polytechnic Institute of Brooklyn has been almost equally divided between these two types of course offerings; more recently, a much larger proportion of students is enrolled in degree programs.

Little need be said about the first type of graduate course serving specialized needs. With a well-selected group of instructors, either from the Institute or from Industry, a high level can readily be set and the enrollment becomes a direct function of the level of the course.

The Evening Graduate School

More should be said about complete degree programs offered in the evening. *Our philosophy* and objectives have been exactly the same as those of any strong day graduate school: training in fundamental methods of analysis, research, and synthesis leading to a critical understanding of the basic principles and a thorough mastery of the knowledge, in a chosen field. As a matter of fact, the generally high caliber of the students has permitted and invited great emphasis upon fundamental courses in mathematics and physics to provide the proper foundation and furnish the powerful tools, for advanced study.

Because of the usually wide experience in laboratory work that the evening students from research and development laboratories bring to the class, the discussion and presentation of the subject matter are kept at a high standard. The students are primarily interested in the basic connecting theory, and in the transition from the theory to the application rather than in any descriptive information pertaining to applications. It is characteristic that these students state preferences for *specific teachers* and select courses frequently because of the teacher rather than because of the subject matter. Training in the professional subjects need not be considered one-sided, because most of these students have had the maturing experience of years of contact with fellow professional men.

Graduate admission proceedings in the evening are, by far, not as critical as graduate admissions in the day school. Keeping the standards high, any weaker student who might have drifted into a class will eliminate himself in very short order. As a result, *the natural selection* will leave only well-qualified students to come up for candidacy for the Master's degree, which, in the usual case, is two years after the entrance of a student into the evening graduate school. Indeed, there exists a rather strong discontinuity in the transition from undergraduate day courses to evening graduate courses which has presented a real challenge even to the best of students continuing directly after graduation from the day undergraduate program.

The *more mature* type of the average evening student makes it imperative to have a faculty with industrial, experience which can stand searching questions. In many instances, the student may know more about a specific sector of a field than a teacher; however, the broad background and training of the teacher must make it possible for him to give a satisfactory reply concerning the analysis of the problem, and its relation to fundamental theory. It has been our practice not to appoint any one to the graduate teaching faculty who has not had several years of pertinent industrial experience. On

POLYTECHNIC INSTITUTE OF BROOKLYN

Graduate Program in Electrical Engineering

Basic Course Group

Functions of a Complex Variable I
Transients in Linear Systems
Vector Analysis
Electromagnetic Theory
Advanced Electrical Measurements

Major Course Groups

Electric Power

Power Transmission and Distribution
Theory of Electrical Machines
Power System Stability
Design of Electrical Machines
Advanced A-C Machinery
Advanced Design of Electrical Machines
Servo-Mechanisms
Analysis of Non-Linear Systems
Insulation of Electrical Apparatus

Also selected courses from Mechanical Engineering and from Westinghouse Program

Electronics and Communications

Selected Topics in Electromagnetic Waves
Microwave Components
Radio Propagation and Antennas
Microwave Networks
Network and Filter Theory
Analysis of Non-Linear Systems
Advanced Network Theory
Electron Tube Theory I, II
Electron Optics I, II
Pulsing and Synchronizing Circuits
Broadband Amplifiers
Feedback Amplifiers
Radio Noise and Systems of Modulation
Television Colloquium
Electronic Measuring Equipment
Advanced Electroacoustics
Sound Engineering

Also selected courses from Westinghouse Program

Electrophysics

Introduction to Theoretical Physics
Fundamentals of Mechanics
Statistical Mechanics
Fundamentals of Electron Theory
Fundamentals of Radiation
Quantum Mechanics
Theory of Solids
Modern Methods in Electromagnetic Theory

Also selected courses from Applied Mathematics and Physics

the other hand, an area as rich in prominent research scientists and engineers as New York, allows to draw upon the part time services of outstanding experts in the respective fields for certain specific graduate subjects. This enhances the graduate program, provides interesting contacts for the students, and gives an acknowledged satisfaction to the associated lecturer.

As a natural development of the stress upon fundamentals, close liaison and, indeed, collaboration between the departments of Physics, Mathematics, and Electrical Engineering were established very early. Thus, in 1936, a program of five comprehensive interdepartmental courses in classical and quantum physics was introduced which could be chosen as a major group for the doctor's degree under the heading "Electrophysics." More recently, courses in basic applied mechanics have been added to this group.

Since the time of contact between teacher and class is restricted to a few hours per week, it is very important to amplify class lectures by home assignments requiring extra reading and study. Home assignments should be carefully corrected and returned for resubmission if they were found wrong, or for the student's file if they were found correct. To many students, these problems form an important supplement to the lecture notes.

Administration of the Degree Programs

The administration of graduate degree programs in the evening poses a few problems not present in the day graduate school. Usually, the evening study for the Master's Degree consumes between three and four years, our average being 3.25 years. The Doctor's Program will take, additionally, five to six years of evening study. This makes continuity of effort, contact with the student, freshness of knowledge some of the real problems. It is the more encouraging that the level of actual programs can be kept high. Details of the degree programs will perhaps best illustrate this point.

The *Master's Program* includes as required courses: Vector Analysis to be followed by Electromagnetic Theory, and Complex Functions, followed by Transients in Linear Systems. The course Electromagnetic Theory is taught with full use of Vector Analysis. It presents Maxwell's theory and the basic applications to static field problems, eddy current problems, and radiation problems encountered in research and design practice. The course Transients in Linear Systems reviews classical and operational methods and then applies function theory in connection with Fourier and Laplace Transforms to lumped networks and transmission lines. Of the total of 30 credits required, these prescribed courses constitute 12. Eight additional credits are allowed for thesis, which is required of all students. It must evidence independent and creative thinking and is usually the best index to establish research ability in the case of men interested in going on towards the Doctor's Degree. Upon completion of one-half of the Master's program and before permission for thesis registration is given, the student applies for "candidacy" for the degree which initiates a review of his performance and leads to pertinent action by the program administrator.

The *requirements for the Doctor's Degree* beyond those for the Master's Degree include Advanced Differential

Equations, Analytical Mechanics, and either Statistical Mechanics or Quantum Mechanics. The student must pass a qualifying examination in his major field, which is the field of his dissertation, and he must show satisfactory course performance in two minor fields, usually mathematics and physics, before he can be admitted to "candidacy" for the degree. In order to guide the planning of the student over the long years of his study, a *Guidance Committee* is appointed about one or two years after his completion of the Master's Degree, and after he has been able to definitely select major and minor fields. This Guidance Committee plans and supervises the student's program, taking into account his preferences, his experience, and his previous training. Every doctorand has thus an individualized program of study and personal contact with graduate faculty members which give him confidence of achievement and give us the first hand information so necessary for the higher degrees. It is also obvious that endurance is an important factor in addition to ability.

The greatest stress in the Doctoral Program is, of course, on the dissertation which *must* constitute an original contribution. Where it is possible, we try to induce a student to study his last year for the Doctor's Program on a full time basis as a Research Fellow, in order to concentrate all his effort on the dissertation with only some minor course work. If this is not possible, then arrangements for shorter leaves of absence are usually made to permit the final spurt to the finish.

The scheduling of a full graduate program within the comparatively small number of evening hours available presents a particularly difficult task. Recourse must be taken to give courses in alternate years and, in fact, a few of the top courses might be given only every three years. The magnitude of this scheduling problem can best be judged from the fact that, at present, our graduate program in Electrical Engineering comprises 35 courses, of which 11 are full year courses; to this must be added at least 10 courses each in Physics and Mathematics. On the other hand, to accommodate the large number of graduate students requires many course offerings so as to hold the classes to reasonable sizes and preserve close student contact. The table illustrates this course program.

About Evening Study

Criticism has been made that evening students cannot possibly perform as well as day students since they must be tired after a day's work. If study for advanced degrees in the evening calls for special effort over and above that of the day student, it could only mean that, by laws of natural selection, only the best will endure. Surely, one has to anticipate the many human problems that might temporarily interfere with the pursuit of study, such as marriage, addition to the family and the like. But married students with understanding wives are more conscious of their responsibilities and represent the most serious types of students. It has been our experience that every instructor who comes into contact with our evening graduate student body experiences a more satisfactory response to his teaching, and finds greater challenge in the questions raised than with day students.

There also has been criticism by Industry that men who pursue evening study reduce their effort for the em-

ployer. However, young people will seldom forego all pleasures of life and a long evening of entertainment is surely more detrimental to the next morning's performance than serious devotion to home assignments and study. It has been our experience that upon receiving advanced degrees, students usually find advancement or more responsible assignments in their company; there must, therefore, be some compensation to the employer in the advanced knowledge gained which should make worthwhile encouragement of graduate study for its own sake.

Discussion of Report on Present Day Salaries in Engineering Schools*

By THORNDIKE SAVILLE

Dean, College of Engineering, New York University

The writer was a member of the Executive Committee of the Administrative Council which authorized the investigation by Dr. Jackson and his colleagues, the report which was completed and presented at the June 1947 Annual Meeting of the Society in Minneapolis. When the matter was originally under consideration, it seemed to be highly desirable to have the salary situation in engineering colleges reappraised, particularly when it could be undertaken by such an experienced person as Dr. Jackson, whose admirable report on "Status and Trends in Engineering Education" in 1939 contained comparable statistics with respect to engineering salaries. However, in view of circumstances which have developed since the study was undertaken and completed, I am somewhat doubtful as to its real value at this time. On account of the general salary and wage situation in the United States which has developed during the past two years, and which was hardly anticipated when the present report was begun. I am inclined to think it would have been wiser to have deferred the study for a year or more.

* The "Report of the Committee on Present-Day Salaries of Members of Instructional Staffs of Engineering Schools" appeared in the September, 1947, issue of the Journal of Engineering Education.

The statistics presented by Dr. Jackson in this report are certainly of current interest, but there is grave question in my mind as to how accurate they are at present, nearly a year after the statistics were compiled. During this year there has been a substantial general increase in engineering college salaries throughout the country. While this doubtless has not kept pace with increases in salaries of engineers of comparable attainments otherwise employed, nonetheless certain of the data in this report may be invalidated as of current applicability. I suspect that engineering college salaries are catching up with salaries on the outside, although they will never catch up fully, and it is questionable in my mind whether on the average this is necessary or desirable for reasons which I shall state.

Dr. Jackson refers to the increasing amount of service which engineering teachers render outside of the academic year, in connection with summer teaching and sponsored research, as well as work with industry and consulting services. He did not comment on the amounts of income thus received, and no information of this sort was gathered on the questionnaires. I think that a very large number of our engineering college teachers do receive such additional compensation, or at any event

have an opportunity to receive it, and that it represents a very substantial factor in any comparison of the annual compensation of engineering teachers with those of practicing engineers outside of the institution. I see no reason to compare the annual salary received by a man in an engineering college for working 9 to 9½ months with that of an engineer practicing his profession outside who receives an income for 11 or 11½ months work. The college teacher also has vacation periods within the college year which are substantial, including the Christmas and Easter holidays, and time during examination periods and between terms. Furthermore the matter of tenure and security should not be overlooked, as providing additional attractions to the engineer in teaching. The conditions of work are by no means comparable, and therefore the salaries should not be compared without explanation. I think there has been too much of a tendency to overlook these factors in the Jackson report and in certain other reports which have recently come out dealing with engineering college salaries.

Dr. Jackson has recognized this situation, and suggests that information should be developed on (a) institutional policy for payment of supplementary compensation and (b) on procedures for paying staff members who work on contract research for industry or government. I thoroughly agree that such information should be collected and analyzed. I think that the ASEE might well conduct a survey on these practices just as it has done with respect to the basê salary situation in the past. We will then have comparable figures with respect to our own profession to compare with those for all professions or other specified professions.

I should hope that perhaps by another year the Association may find it desirable to have Dr. Jackson's data reanalyzed and reinforced by additional information of the sort mentioned above. In fact, on account of the probable greater stabilization of engineering college salaries beginning September 1, 1948, I should like to recommend that in spite of the short time elapsing between reports, we have a resurvey made of the whole salary situation at that time.

Such a study might well include the following specific factors which have a bearing upon the annual income of engineering college teachers:

(a) Base salary, stating number of months service required.
(b) Required teaching load in class hours per week.
(c) Class-hour equivalent of laboratory and design hours.
(d) Number of full time staff in each grade.
(e) Total and average amount paid to each group (instructor, assistant professor, etc.) for (1) teaching outside of period covered by base salary, and (2) work on contract research.
(f) Institutional regulations governing work performed under (e) above.
(g) Institutional regulations governing allowance for time on fundamental unsponsored research.
(h) Institutional regulations governing private consulting work, (a) during period covered by base salary, and (b) during other periods.

I do not pretend to say that engineering college teachers salaries are too low or too high, or that they are

satisfactory. I believe that they should be raised on the average. On the other hand, I do not think we should make specific claims of underpayment by quoting salaries publicly which in the first case are based on 9 or 9½ months employment, and in the second place do not include substantial supplementary income from various sources. Generally speaking, salaried engineers of comparable abilities in outside professional practice do not have opportunities for such supplements to their regular salaries.

Dr. Jackson seems to feel that "if the average salaries at every engineering school approached the values of Chart 11 of mediums of average salaries (for the ten highest paying schools) a much larger proportion of young engineering graduates would be attracted by the possibilities of the teaching profession." However, we must recognize that salaries of all professional employees are generally governed by competition and the general salary ranges in a given geographical area. Certain areas of the country will always reflect higher cost of living by greater compensation than will other areas, and I see no reason in ethics or economics for attempting to have a uniform scale of pay in our engineering schools throughout the entire United States.

The geographical differences in salaries paid in 1946 follows the same pattern as in previous reports. This is natural, and I think indicates possibly two factors. The first is that we should not compare average salaries throughout the United States, and the second is that salaries in certain geographical regions ought to be increased. I suspect (without statistical proof) that the low paying regions are unduly low, whereas the high paying regions are about right. It is indeed possible that some of the institutions in the high paying regions may be paying unduly high salaries at present, since for a year or two the demand has been exceedingly great, and the supply scarce, and some of these institutions have been able to draw upon endowment and other funds precluded to the publicly supported institutions in the low paying parts of the country.

As a matter of fact, quite aside from geographical implications it is entirely conceivable that the desperate scramble and severe competition for personnel among engineering colleges during the past year or so will have admirable results in the future, in that salary scales may be pushed up in the course of the present year to a point where they will be quite attractive when the supply of engineers becomes greater, and the demand less acute. I suspect that salary scales for engineers generally will not increase substantially in the next few years, and that salary scales for engineering teachers will more nearly approach a competitive status with those offered by industry and government for comparable personnel. Indeed I suspect that we are not far from this situation in many parts of the country today.

May I suggest that in appraising the statistical data of this report, reference be made to the Engineers Joint Council report on "The Engineering Profession in Transition" which contains an elaborate study of the salary situation of all engineers throughout the United States for 1946. The data are therefore comparable with those in the Jackson report. One may gain an impression from reading the E.J.C. report that on the average engineering college teachers salaries are not badly out of line with the averages paid for engineering services throughout the country. I do not

wish to take time to go into details, but I think a comparison of the data in the two reports will interest many in this audience.

The report notes that the median of maximum salaries for the professorial group is greater than for the department heads. It is stated this is because three of the ten highest paying institutions do not have permanent rank of department head It may also be due to the analytical process used by Dr Jackson in assuming that department chairmen salaries are on a 12 month basis, whereas full professor's salaries are on an academic year basis. Should this be the case (and I am inclined to think it is not true on the average), the rate of compensation of the full professor as compared with the department chairman is even greater If there is a real tendency in this direction I should hope that what I consider to be an exceedingly desirable arrangement was in effect at a number of institutions: namely that the department head was not necessarily the highest paid member of the department. I think the sooner we get away from the idea that the administrative officer of a department must necessarily be the highest paid man in the department, the better off we will be. More often than not we have to destroy a large part of the genius and scholarly attainments and production of our best teachers and scholars in order to pay them a remuneration which can only be effected by making them department chairmen, thereby swamping them with administrative duties which are burdensome and frequently distasteful. A good department head is certainly to be highly prized, and should receive relatively high compensation. However, I see no reason per se why he should receive higher compensation than a noted teacher and scholar.

Finally, may I comment briefly upon the concluding remarks of Dr. Jackson. These consist in part of quotations from an article by Professor Sumner H Slichter of Harvard which was published in the *Bulletin of the American Association of University Professors* in the winter of 1946. It is stated in the Jackson report that Professor Slichter's observations are based upon "a study of the returns from 88 colleges and universities." It think it might be well to point out that the study by Dr. Slichter was based solely upon the minimum salary of full professors at the 88 institutions involved. No other information was requested and no other information was given. Accordingly, analysis of the conclusions which are given in the report ought to bear this statistical fact very clearly in mind.

Several of the comments at the end of Dr. Jackson's report seem to me to be intended as conclusions, and indeed were originally reported as such, but actually have little to do with the factual material of the report itself. These comments deal with internal administration of engineering colleges and of universities in general Inasmuch as the report did not analyze the administrative and budget making policies of the colleges under study, the remarks relating to these subjects would seem to me to be somewhat extraneous to the subject matter of the report.

May I perhaps be permitted to anticipate a little the remarks of the next speaker, especially as I am largely responsible for his appearance here. When I was asked to discuss the Jackson report I stated that I would be glad to do so briefly, but that I thought constructive suggestions relating to procedures for the establishment of grades

and corresponding salaries would be more to the point. I therefore suggested that Professor Lilly of Swarthmore be asked to address the Administrative Council for the reason that he has been making some very unique studies in connection with the Committee on Salaries of the American Society of Civil Engineers. His studies relate particularly to salaries in the engineering teaching profession, and while I have not agreed altogether with his tentative conclusions, I do feel that his method of attack is novel and stimulating. If it can be developed with the help of agencies such as the Administrative Council of ASEE so that it can be generally applicable throughout the country for establishing yardsticks for measuring the various factors which enter into salaries and ranks, I think we shall have taken a very substantial step forward. To my mind it is rather an Utopian idea at present, but the more I have seen Professor Lilly develop his thinking in this matter, the more I have felt that ultimately he may produce an exceedingly useful method of analysis, which if properly used and interpreted may not only assist in the establishment of adequate salaries for engineering teachers, but will be of substantial assistance to engineering college administrators in establishing salary scales. If we can develop some procedure for discovering and rewarding good teachers, as contrasted with the more readily apparent worth of research, we may be able to counteract a tendency which I believe is unfortunately too prevalent at present, whereby many administrators are rewarding faculty members for research and overlooking the equally or more important function of inspired teaching because it is more difficult to appraise.

A Common Field of Graduate Research in Engineering[1]

By O. A. HOUGEN

Professor of Chemical Engineering, University of Wisconsin

"In some fields of engineering practice little or no premium is attached to graduate studies in advanced technical subjects. In the practices of mechanical design, construction, contracting, and plant operation it is generally conceded that the most suitable training, following the bachelor's degree, is secured on the job under the guidance of expert engineers and through the pressure of practical performance. After the bachelor's degree the value of practical experience in the foregoing fields more than offsets the possible gain secured by further technical studies in college. There is a possible risk that too many years of academic training may jeopardize the acquisition by the young engineer of confidence which can best be gained during the formative years. Furthermore, in certain fields the University can ordinarily not afford the faculty nor supply the necessary motivation. The most successful engineers in these fields have secured their advanced training under guidance of experts and under the pressure of the job and the necessity of successful performance."[2]

On the other hand, in the fields of process design there has developed an urgent demand and need for engineers trained in graduate studies leading to the master's and doctor's degrees. The research and technology underlying modern process design call for the combined skills of every branch of engineering. I have designated this as a common field of engineering research, the topic of this paper. In process design the demand for advanced training is as acute today as it was for undergraduate training thirty years ago.

Meaning of Process Design

By process design is meant the engineering research and planning that go into the development of a production or manufacturing operation. Process design is to be distinguished from mechanical design. Mechanical design involves the design of the constructional details of equipment, machinery, and buildings. Process design deals with the selection and specification of process equipment, with plant-layout according to process flow charts, with establishing the proper size and shape of reactor vessels, and the most favorable and economical conditions of operating each apparatus with respect to all variables. Process design is centered about problems of rates of mass

[1] Presented at the Conference of Graduate Studies, A.S.E.E. Annual Meeting, Minneapolis, June 18, 1947.

[2] Parts of this paper in quotations have been taken from the report of the Planning Committee of the College of Engineering, University of Wisconsin, June 5, 1947.

and heat ·transfer and of chemical change. These production rates are frequently classified under the two categories of unit operations and chemical kinetics.

It may appear to some that the field of process design is largely the concern of the chemical engineer. Where chemical processes are involved this may be the case, but further reflection will show that research problems in process design involve each major field of engineering and provide a common field of engineering research.

The practical objective of process research is to provide scientific data which will permit the rational design of a manufacturing process with the minimum time and equipment spent in pilot plant studies and to operate the final process under the most favorable and economical conditions with respect to all variables such as feed composition, space velocities, recycling, heat and power requirements, and temperature gradients. The objective is to reduce the time and expense of translating a process from a small laboratory scale to full size plant construction. Frequently many years and hundreds of thousands of dollars are needed for this transition. Lack of knowledge of the principles of dimensional similitude is responsible for many of the failures in attempting to translate laboratory experiments to plant scale operation. Scientific methods of process design are as yet not widespread in industry. In the past chemical plants were constructed from experience by trial and error methods; today such plants are being constructed for stream-line production with balance and proportion and with economy in space, materials and energy as the result of scientific research. The petroleum industry of today is in particular characterized by its employment of scientific procedures in the design of equipment for compact and continuous performance in the operations of heat transfer, fluid flow, distillation, and in the processes of hydrogenation, catalytic cracking, alkylation, and polymerization. Particularly good examples of modern rational design based upon process research are to be found in the production of high octane gasolines, the recovery of bromine and magnesium from sea water, the production of phosphoric acid, and the manufacture of nylon and synthetic rubber.

Training Required for Process Design

The technical knowledge involved in process design includes material and energy balances, mass and heat transfer by convection, diffusion, and turbulence; the flow of fluids through granular beds, packed towers, and plate columns; the separation of materials by distillation, extraction, filtration; the thermodynamics and equilibria of reacting systems, the behavior of catalysts and the kinetics of all types of chemical reactions. These are the factors that determine the size, feasibility, and conditions of economical operation. In process design are also included the selection of materials of construction and problems in instrumental record and control of temperature, pressure, flow rates, liquid levels, feed ratios, and composition. The technical skills required in process design involve a comprehensive training in mechanics, machine design, electricity, thermodynamics, materials of construction, hydrodynamics, chemistry, physics, and mathematics.

"With the growing complexity of industry, with the greater ingenuity required in the processing of our dimin-

ishing mineral resources; with the advancing production of synthetic materials, plastics, and elastimers; with the new developments in instrumental control and analysis; with the new era of electronics, catalytic processing, and atomic fission, the need for broader fundamental training becomes increasingly greater. In this complex scientific age research engineers are required to have some familiarity with many advanced subjects, such as electronics, vibrations, elasticity, advanced hydrodynamics, chemical kinetics, chemical thermodynamics, atomic structure, physical chemistry, and nuclear physics. In branches of process engineering dealing with the food, pharmaceutical, leather, and fermentation industries there is the additional demand for training of the engineer in biochemistry and bacteriology. A broad composite scientific training is often demanded in a single individual who is to undertake direction of research, development, and design in modern process industries."

"It is evident that research in process design calls for training in advanced fields of science which can be obtained best in graduate studies at a University rather than in practice. It is common experience that advanced studies in mathematics and the physical and chemical sciences are rarely acquired by individual studies removed from the pressure of daily class-room assignments."

Common Problems in Process Design

It is evident that the research problems in process development spread into all fields of engineering and call for cooperation among the different departments of engineering. Researches in heat transmission are of common interest in chemical, mechanical, metallurgical, and electrical engineering. The hydraulic engineer may gain ideas from the researches conducted by others in the flow of fluids in distillation columns, tower packings, and granular beds and with the greatest variety of gases and liquids. The operations of evaporation, condensation, humidification, and the processes of refrigeration, combustion, and air conditioning are common to both chemical and mechanical engineers. The chemical engineer has followed the mining engineer in studies and researches on mechanical separation, filtration, sedimentation, settling, flotation, and classification. The mechanical engineer is confronted with the most complicated kinetic problems in the performance of internal combustion engines; to date these problems have been too complex to benefit much from the researches in the kinetics of combustion, but the time for helpful collaboration is at hand. Similarly, the design problems of sewage treatment have been too complex to benefit much from bacteriology and organic chemistry, but these fields will soon be drawn together in more helpful cooperation. In problems of process design the selection of materials of construction is involved with corresponding information on strength of materials and resistance to creep and corrosion. In problems of process design instrumental measurements and controls are required with all the research involved in developing suitable electric circuits and mechanical devices. Similarly, rapid and continuous methods are needed for the determination of chemical composition by instrumental methods using the mass spectograph, spectrophotometer, refractometers, conductivity meters, and other devices.

Need for Graduate Research

I shall close this discussion with a plea for greater emphasis upon graduate work and research in engineering. Today there is a shortage of 17,000 Ph.D.'s in fields of physics, chemistry, and engineering. Even though the greatest financial returns in engineering have come through positions of management and production, many young engineers are attracted by the opportunities for original and creative work in graduate studies and research and are peculiarly qualified for these activities. "If it were not for graduate instruction and research in our colleges and universities less advance in fundamental principles and theory would be made and fewer new scientific principles would be developed, progress in some directions of science would mark time. For its source of fundamental principles engineering has drawn largely upon the researches of advanced students in physics, mathematics, and chemistry. But even in the engineering applications of these theories there would be little progress without additional research and studies. Textbooks and handbooks would not exist or would soon become obsolete if it were not for the pressure of advanced studies and research. Engineering colleges with no graduate or research programs must lean upon others for professional advancement. Without graduate work and research, courses become sterile and repetitious. Engineering courses should be in a continuous state of flux with discard of that which is obsolete and replacement with the new. There is the danger that professors without research or consulting activities, or without contact with industry, research and graduate students soon become out of date. There are instances where theories long outdated are still being taught to the exclusion of modern theories. Without the stimulus of research and graduate studies, it is difficult to keep pace with the development of engineering principles."

The benefits of graduate studies and research rapidly leaven and enrich the work of undergraduate instruction, forcing out the old and bringing in the new. "The effectiveness of undergraduate instruction is usually determined by the interest and capacity of the instructor. An instructor who himself has not had experience in research and graduate studies is not well qualified to guide others in these directions. The value of graduate work and research should be recognized in the appointment and qualifications of the faculty."

"In fundamental engineering research the engineering faculty should lead and not wait for industry to take the initiative. Industry looks to the university for enlightenment and guidance in the advancement of theory. Industrial leaders and engineers are too preoccupied with the problems of production and profit to keep in touch with theoretical developments and do not recognize the value of theory until demonstrated in practice. In the past, practical applications have followed the discovery of scientific theories often by hundreds of years. Today the gap between theoretical advances and practical applications has become short. Indeed the curtailment of theoretical research during the war nearly closed this gap between the stage of scientific knowledge and its application. With the expansion of industrial research laboratories and increasing recognition of the value of research, the need becomes even more acute for the colleges of engineering to engage in fundamental research and to train students in advanced theories."

Education and Practical Training of Mechanical Engineers in the United States*

By ROBERT E. DOHERTY
President, Carnegie Institute of Technology

It gives me pleasure to bring to the Institution of Mechanical Engineers, on the occasion of its Centenary celebration, warm greetings from engineers and educators in the United States. I count it a great honor to participate in the program and discuss with you the education and practical training of mechanical engineers in my country.

The route by which mechanical engineers, during the past 75 years, have reached professional competence has of course undergone evolution from the beginning—slow on the whole, but seeming now to be on the threshold of more rapid development involving some new directions. This evolution, as regards formal college education, has been from a dominant emphasis upon practical training in the early days, toward greater emphasis upon the scientific foundation which underlies mechanical engineering and upon the economic and management phases of engineering activity; and, as regards the process of acquiring practical experience in industry, it has moved from an unplanned program of on-the-job experience towards more purposeful schedules to this end. The new turn which this evolutionary movement is now taking involves not only further progress towards the ends I have just mentioned, but also a fundamental revision of the concept of the engineer as a professional man, and therefore a corresponding revision of his educational requirements.

I shall discuss formal college education in the paper itself, and practical training in the Appendix.

EDUCATION

Present status and trends in education may be understood better if, as it were, we compare two points on the curve—say 25 years ago and now—and then examine carefully the slope at the second point. We shall compare these two points in terms of the requirements for the B.S. degree in mechanical engineering, status of graduate work, growth of specialized curricula, influence of the profession, enrollments, technical institutes, etc.

From the early programs established about 1870, formal education moved along the lines I have just drawn, the movement toward the basic sciences being especially marked after 1890. The appearance of the electrical engineering curriculum in the 1880's, and later of chemical engineering—both of which had sprung from science curricula—naturally influenced the evolution of the mechanical engineering cur-

* **Address delivered at the Centenary Celebration of the Institution of Mechanical Engineers, London, June, 1947.**

riculum, which itself had sprung from more practical beginnings. At our first point, some 25 years ago, the representative four-year curriculum in mechanical engineering, leading to the Bachelor's degree, was, so far as subject matters are concerned, roughly as indicated in the first column of Table I.[1]

TABLE I

REPRESENTATIVE REQUIREMENTS FOR THE B.S. DEGREE IN MECHANICAL ENGINEERING

Subject	Required Semester hours 1923	1946[2]
Mathematics	16	16
Physical science	19	23
Humanistic-social	13	22
Mechanical engineering	53	42
Other engineering	39	30
Miscellaneous	10	4
Total	150	137

(Totals do not include military—and physical training)

The second point on the curve is indicated by the 1946 column. Comparing these columns, we find, first of all, a reduction in the over-all requirements As to the components, one finds no change in mathematics, a small increase in science, but a reduction in engineering subjects to make room both for an increase in humanistic-social subjects and for the general reduction. Despite the former, the foreign language requirement was reduced. The amount of shop work in the curriculum was decreased.

Other educational trends between the first and second points are not explicit in Table I. In 1923 industrial management had become a recognized area in the field of mechanical engineering. By then 17 engineering schools—roughly 12 per cent of the total—had established special curricula in this area. The trend continued during the next 25 years, so that now 29 schools [3] have such curricula approved —or, as we say, accredited—by the Engineers' Council for Professional Development.[4]

There has also been a trend toward a multiplicity of specialized curricula and courses. The advances of science and the tremendous increase in the scope of its industrial applications have of course brought newly defined specialized industrial fields. These changes have been reflected both in the organization of the profession and in education. Mechanical engineering has not escaped. For example, in the profession [5] there are now separate

[1] Wickenden Report, S.P.E.E. Investigation of Engineering Education, 1923–29, averages from data on pp. 482–484.

[2] Averages based on data from catalogues of the following institutions: Cornell University, Massachusetts Institute of Technology, Pennsylvania State College, California Institute of Technology, University of Illinois, Carnegie Institute of Technology, Lehigh University, Illinois Institute of Technology. All of these except California Institute and Illinois Institute are represented in first columns. Mathematics: at least through integral calculus. Physical science: at least elementary physics and chemistry. Humanistic-social: principally English and economics, but also such subjects as history, foreign language, business law. Mechanical engineering: subjects given by mechanical engineering department. Other engineering: subjects such as electrical engineering, mechanics, engineering drawing, etc. Semester-hour: one hour per week in class for one semester—a term of some 18 weeks.

[3] Engineers' Council for Professional Development Report, 1945, p. 25.

[4] A conference, created in 1932, of 3 representatives each of six engineering societies (including the Engineering Institute of Canada), the engineering educators (S.P.E.E.), and the National Council of State Boards of Engineering Examiners.

[5] C. E. Davies, Organizations of Engineers in United States, International Technical Congress, 1946, p. 5.

organizations in the following fields: heating and ventilating, automotive, aeronautical, refrigeration, agricultural. In education, these and other related fields are represented in special curricula.[6] And the number of specialized individual courses is almost beyond count.

Another significant change has been the great increase in graduate work. In the early 1920's fewer than 100 advanced degrees were conferred annually in *all* branches of engineering, and practically all of these were the Master's degree. In 1940 there were 1329 Masters' degrees and 108 Doctors' degrees, of which 170 Masters' and 7 Doctors' were in mechanical engineering. In 1946 there were 1036 Masters' degrees and 82 Doctors', of which 178 Masters' and 10 Doctors' were in mechanical engineering.

Professional influence has of course also been felt. The Society for the Promotion of Engineering Education[7] has been most influential in bringing about a clear formulation of purpose and in encouraging engineering teachers to adopt it, as indicated later. One of the primary functions of the Engineer's Council for Professional Development is to accredit curricula in engineering. In the 1920's there were some 150 colleges offering curricula in engineering. In spite of the great increase in students, the number of such colleges has not increased, and only 133 of them have accredited curricula. Another result is the definite restraint by this Council upon the continued multiplication of specialized curricula. The American Society of Mechanical Engineers has also been influential by bringing practicing engineers and college teachers together in conference. State laws require that practicing engineers be registered. Qualifications for registration are represented in E.C.P.D.'s programs.[8] And, of course, the increasingly exacting professional requirements of industry have had their effect.

There has been a growing tendency, especially in view of experience in training technical personnel during the late War, to recognize the important role which technical institutes —roughly similar to the local technical institutions in England—should play in the whole scheme of technological education. In order to assure a better balance between the roles of the engineering college and the technical institute, the E.C.P.D. has now undertaken the accrediting of these institutes.[9] Also, an increasing number of junior colleges have offered elementary courses in engineering.

Another strong trend has been the increasing percentage of practicing mechanical engineers who are college graduates. It is estimated that 80 per cent of the present membership of A.S.M.E. are graduates, and 97 per cent of the new members.

And finally I mention the increase in enrollment. In 1922 there were 56,649 enrolled in engineering colleges; in 1940—the last prewar year— 110,618, of whom 28,600 were in mechanical engineering; and in 1946, an abnormal year, over 200,000, of whom some 43,000 are in mechanical engineering. Large numbers are temporarily appropriate, in order to offset the

[6] Annual Report, Engineers' Council for Professional Development, List of Accredited Curricula, 1945, p. 23.

[7] Now the American Society for Engineering Education.

[8] E.C.P.D. Annual Report, 1945, p. 31, Definition of an Engineer.

[9] Ibid., p. 14, Technical Institute Accrediting Program, H. P. Hammond.

deficit of new engineers due to the War.

Having compared the two points on our curve, as regards formal education, we shall now examine the slope at the second point. What are the educational trends now?

I have said that great changes are now getting under way in all branches of formal engineering education. These are aimed at placing greater emphasis upon fundamentals that lie at the center of scientific and engineering knowledge, and less upon the specialized information and "know-how" that lie at the periphery; and at recognizing social and civic responsibilities, and preparing the student for them, and thus for a worthy personal and professional life. The velocity of change is as yet low, but the acceleration is high.

The new philosophy of engineering education and the formulation of definite objectives were stated in 1940 by the S.P.E.E.[10] and endorsed by the E.C.P.D. The objectives were reviewed and reaffirmed by both organizations in 1944.[11] Although the new outlook had become focused in the earlier Report, it is, I think, fair to say that the recommendations were at first received by engineering faculties with only mild enthusiasm. The War, however, had its impact on educational thinking[12] and brought a more general acceptance of the new outlook. Thus, with this added impetus and the sponsorship of these two professional bodies, in both of which mechanical engineers are represented, this new movement is under debate in every engineering faculty. Many of them have reached the stage of definite planning, and new programs are in effect at some institutions.

The central recommendations of the second S.P.E.E. Report, looking to the implementation of the new purpose, are that "the attempt to make the undergraduate student proficient in specialized subdivisions of engineering practice must be abandoned in the interest of developing mastery of basic principles"; there be greater emphasis upon cultivation of creative ability; the utmost care be exercised in the selection and development of engineering faculties; graduate work of high quality be expanded; instruction and research be developed as complementary and coordinate functions; production management be included as a phase of *engineering* activity; the great importance of the role of technical institutes in the scheme of technological education be recognized; in the division of the student's educational time, not less than 20 per cent be devoted to the humanistic-social studies; these studies be planned so as to constitute "a unified, developing sequence extending through the curriculum."

These recommendations created problems. The four-year curriculum is already crowded without room enough even for scientific and technological subjects. How then could the humanistic-social content be practically doubled? There are two schools of thought. One would lengthen the undergraduate curriculum to five years. The other would cut down specialized courses to make room and let the student specialize on the job after graduation, or continue for one, two, or three years in graduate

[10] "Report on Aims and Scope of Engineering Curricula," *S.P.E.E. Proceedings*, Vol. XLVII, pp. 555–566.

[11] "Engineering Education After the War," *S.P.E.E. Proceedings*, Vol. LI, pp. 589–614.

[12] For further example of direction of thinking, see "Engineering and Human Affairs," Princeton Bicentennial Conferences, October 2, 1946.

work. Four institutions have recently adopted the five-year curriculum—Cornell, Ohio State, Minnesota, Louisville. A few have followed the other course. The rest are struggling with the problem. It is a stubborn issue.

Another is the related long-run *versus* short-run issue. Should education prepare the engineering student for continuing professional growth or for immediate proficiency in engineering routines? In other words, should more of his time be devoted to a mastery of fundamentals and less to specialized study, or the other way around? The S.P.E.E. Reports, endorsed by E.C.P.D., are clear on this point: prepare for the long pull. But the pressure from small industries is opposite. Most of the large manufacturing industries, however, favor the S.P.E.E. proposal.

Still another critical problem is the shortage of qualified teachers, and this problem is now aggravated, and others created, by the overwhelming student enrollments. Thus, engineering educators in the United States have their hands full.

May I now venture a personal view. The need of America—indeed of the world—goes far beyond mere technical requirements in engineering education. Especially in a democracy, and again in a complex technological age, the need of disciplined professional intellects that can recognize and cope with the great issues of our rapidly evolving civilization, transcends all other needs I know. And this need is pointed directly at the engineering profession which, with the scientists, has had increasingly great responsibility for the drastic changes in the human environment and hence also for competence of its members to foresee and to deal with the social and economic consequences of their work. The solution of such social problems cannot be left wholly to other professions, as history shows; it challenges the best that all of them can do. Engineers must do their part.

It is the job of engineering education to prepare them to do so, and to this end, as well as for competence in the strictly engineering side of professional practice, I recommend the following two principles:

1. The primary function of formal professional education should be to equip the student to use in subsequent learning and in professional work, an understanding of the fundamental concepts, principles, techniques, and ways of thought of his profession in order that he may develop throughout life in analytical and creative power.

2. Education for citizenship and good individual living should be an integral part of professional education and must not be separated from it. Such education includes assisting the student to develop a philosophy of life and firm sense of social responsibility, and to acquire the basic knowledge and skill necessary to apply to present-day social problems, the realistic, incisive, and well-ordered thought that characterizes good professional thinking.

Let me say that the formal education of mechanical—and all other—engineers in the United States is meeting the challenge of the times. It is late; there is a great lag between all professional education, including engineering, and the needs of society. Social unrest, the stubborn issues between labor and management, and other dislocations that now bedevil us are clear evidence that this lag must be eliminated as soon as possible. The hope is that the intensive attention now being given to pro-

fessional education will close the gap before it is too late.

In conclusion, I hope that I have left with you the clear impression that engineering education in America is informed with a new purpose—a new concept of the engineer as a professional man—and is pressing ahead to accomplish that purpose; and that in practical training, industry is learning the value of a planned program of "internship" and an increasing number of companies are adopting it. And also let me say again that I am gratified at being privileged to participate in the Centenary celebration—all the more so because such meetings tend to bring your country and mine still closer together.

Appendix—Practical Training

The following question was answered by ten manufacturing companies, representing such industries as steel, aluminum, automotive, electrical, aeronautical, machine, and fabrication: How does the college graduate who comes to the company acquire the practical training and experience necessary to become a mechanical engineer?

The replies indicate plans that, of course, differ from each other, but there are a few common elements. In all, the college graduate must serve an "internship" to acquire the necessary practical training. Most of them have definitely scheduled programs, and some have highly developed plans involving class work paralleling the shop or drafting room experience. Certainly the trend in large industry is toward a planned program.

Another method is the "cooperative" plan[13] between college and industry in which the student spends alternate periods on the campus and in the plant. This plan is on the increase. In 1925 there were 16 such plans; in 1941, 33

The plans of practical training in industry are outlined in the following statements:

Aluminum Company of America

During the first few weeks following employment by Alcoa, the mechanical engineering graduate enters a planned training program starting with an orientation course. This includes discussions of the company's history and background, of its products, of the relationship between the line and staff engineering departments, and of the general functions of the operating, metallurgical, engineering, and administrative departments. During this period he may be assigned to various staff departments such as production planning, metallurgy, and industrial engineering, or to some operating department (sheet, extrusions, etc.) where he can observe these activities "firsthand."

Following this orientation period he is assigned to a senior engineer under whose guidance he first performs a wide variety of relatively simple jobs before taking part in general plant mechanical problems. His work on these general plant mechanical problems serves as an indication of his capabilities and future possibilities.

Finally, under the guidance of a senior engineer, the engineering graduate is assigned to specific engineering problems, where he learns the practical application of engineering to specific operating problems, and is then on his way towards becoming a full-fledged mechanical engineer.

Blaw-Knox Company (Machinery and Steel Products)

This company's flexible plan permits each division to develop its own program of practical training.

In the foundry and machine division, for example, the young engineer receives his training in three periods.

[13] "Cooperative Education," *S.P.E.E. Proceedings,* Vol. LII, pp. 395–399, 1944.

First, he learns the product by checking drawings and later detailing equipment under close supervision by an experienced engineer. He spends increasingly more time in the shop, observing and checking the assembly of equipment he has helped to engineer. The second period is outside. Accompanying an experienced engineer, he observes the actual operation of equipment in the field and talks with the men who operate it, thus learning their constructive criticisms. In the third period he assists in smaller installations and the initial operation of equipment. Thus, after several years, he becomes useful in creating new designs and is placed on larger and more complicated equipment.

In another division (steel fabrication) success has been found along different lines. In contrast with the old method of placing the graduate engineer at the bottom, *i.e.*, tracing and detailing in order to teach him the company products and the application of his college training to practical engineering, we have proved that, if charged with some responsibility of design, under high-grade supervision, he can do productive work of a much higher degree during this training period.

Therefore, the young engineer receives regular engineering design assignments in which he meets practice, and learns the engineering principles and formulae which fit the problem at hand. Regularly scheduled trips to the shops familiarize him with the various machines and processes and their functions. He also may learn some "tricks of the trade" from the shop men, so that these shop trips are "education from observation."

Our policy of providing an opportunity for the young engineer to see the results of his efforts is one of the most important phases of his training. When a machine or structure on which he has done design work is completed, he has a chance to see it in operation or erected.

Boeing Aircraft Company

In the Boeing Aircraft Company, practical training for many engineers begins on the drafting board. Indeed this should be the first step for all young engineers—it is the principal means by which any engineer puts his ideas into concrete form. Whereas the young engineer may spend most of his time on the drafting board, as he goes up the scale his work generally becomes less and less design and more and more supervision. However, moving up the scale on the side of supervision requires an increasing understanding of human relationships, based on practical experience and on study. In developing an engineer, it is essential that the man not be forgotten. An understanding of the relationship between design and production is important in training good designers. An understanding of the problem of the shop man expedites more workable design and more economical production. This practical training and practical understanding are achieved by the young engineer through close and continuing contacts with the factory operations which are involved in producing the parts he designs, and in dealing with men in the process.

Carnegie-Illinois Steel Corporation

A mechanical engineering graduate receives training and the opportunity for education throughout his business connection with this company. In general, he secures this by graduated assignments in keeping with his ability, by observation and analysis of the various processes and mechanical equipment, and by assimilating the experience of specialized engineers.

To expedite the process this company has set up indoctrination schedules for the young graduate in the majority of our plants and departments. This schedule usually involves intra- and interdepartmental training, to provide an understanding of the work performed in each department and its relation to the

whole. Minor odd jobs are assigned the trainee in each group responsibility. After a year or two of apprenticeship training the young engineer usually develops a particular aptitude, and he is given a more permanent assignment. His career is carefully followed, and an effort made by management to move him laterally or vertically, as the opportunity presents, to enhance his training.

His early training includes regularly scheduled group discussions and conferences. Educational courses given by competent company engineers enable the young, as well as mature, engineers to receive special knowledge concerning engineering design of various plant facilities; engineering sales and forecast; technological development and research; the business of engineering, traffic, and transportation; metallurgical and methods engineering. Many of these courses are conducted in affiliation with colleges in a program leading to an advanced degree. Such courses provide the opportunity to discuss, face to face with our leading engineers, problems inherent in our industry; to meet associates, key men, and executives of the plant and general offices on common ground; and to acquire a broad perspective of the company's business.

Caterpillar Tractor Company (Diesel engines, tractors, motor graders, earthmoving equipment)

This company has a highly organized training program. There are two plans. One is the cooperative program with engineering colleges, and the other is a one-year orientation program for men who already hold a Bachelor of Science degree.

The cooperative course is conducted in conjunction with either the Illinois Institute of Technology or Northwestern University. The undergraduate spends alternate periods of three to four months in college and in the plant. The trainee learns to operate production machine tools, is assigned a variety of work in the Heat Treat, Foundry, Welding, and Product Assembly Departments. After five years, he receives his Bachelor of Science degree in engineering from the university and is ready for responsible work.

For the company's college graduate orientation program, college graduates of superior ability are selected. The shop schedule includes work on assembly lines and the proving grounds to become acquainted with the company's products, work assignments in engineering design and research to learn how new products are developed, and varied experience in the Heat Treat and Foundry Departments to become familiar with manufacturing procedures.

Class meetings are held weekly on company time. The trainee attends technical lectures and conferences and prepares special reports.

Upon successful completion of this training schedule, the trainee is placed in one of the departments of the company. If further training is required, arrangements are made by the department in which the trainee is placed.

Ford Motor Company

Last year, the Ford Motor Company hired approximately fifty graduate engineers. The one-year training program started with a two-week tour of the Rouge Plant area, under the guidance of the Safety Department. This offered an opportunity to become familiar with the various buildings and the phase of manufacturing accomplished in each. Then the men spent a period of time in every phase of manufacture of the automobile, from the blast furnace and steel mills through the final assembly line. The training in these departments consisted of actual work side by side with production workers, as well as discussions about operations and procedures with supervisors and training representatives. At the end of each period, the student engineer was required to write a comprehensive report of that phase of manufacturing.

In addition, the men spent time in the various service functions connected with the manufacture of automobiles—such as time and motion study, electrical maintenance and repair, process engineering, powerhouse, and the Dearborn Engineering Laboratories where our testing, development, and research activities are performed.

Upon completion of the training, these men were placed throughout the various departments of the company. We have learned that this training has benefited them greatly in successfully performing their first job assignments. We do not feel that this program alone trains a man to be a qualified mechanical engineer. However, his education, a year of training, actual job assignment, and continued study in his chosen field of specialization should contribute to the attainment of his goal.

General Electric Company

The general plan for practical training of college graduates includes two steps: a year or so in the factory, testing manufactured apparatus; and then practical experience in an engineering department. These steps are paralleled by numerous special programs for special groups.

During the first step the trainees have successive three months' assignments in different manufacturing sections; in each they first help with, then have full responsibility for, the tests. They also act as engineering inspectors. After each assignment they are rated on ability and personal qualities.

The second step is in the engineering departments, where the foremost requirement is that the young engineers be placed on interesting and important work and be supervised by a good leader. They must realize that this work is being carefully watched and recognized; have opportunity to learn about the whole job, not merely a specialized part; be given as much responsibility as possible; and see an outlet for future advancement.

The plan is designed to meet these requirements. As examples, merit ratings, on which salary is based, are made on performance in their assignments, which include all phases of design and manufacture. Also, in a special course conducted by the men themselves, they learn from each other the work of the whole division.

An example of special programs is the Creative Engineering Program, planned to discover and develop creative ability. Some thirty young men are selected each year through personal interviews. Hobbies, knowledge of engineering fundamentals, curiosity about design, ability to recall and make use of experience are considered.

The program includes class work to stimulate creative interest, together with engineering assignments under supervision of experienced creative engineers.

Mesta Machine Company (Special equipment for the steel—and nonferrous industries)

Normally, we carefully select each year for training six or eight engineering graduates. They are first placed on assembly work for a period of at least one and one-half years, under the guidance of our Apprentice Training Instructor, where they become familiar with the machinery we produce and gain practical experience from testing.

This first assignment serves also as a selective process. At the end the group is divided according to ability and interests. Some are placed in shop work, with the opportunity to become general foremen and supervisors; some in sales and engineering departments; and some in the engineering department.

Here they are classed as engineering apprentices. In addition to practical training on the drafting board, they are assigned, when possible, to outside installation work or to be observers where trouble may develop in the operation of mill equipment.

After three years they are given the rating of Junior Engineers. Their work and compensation depends subsequently entirely upon their initiative and ability.

These young men are making good as foremen and other supervisors, and as engineers, and they agree that the compensation and practical experience gained during the training have been quite satisfactory.

North American Aviation, Inc.

Because of an increasing flow of experienced personnel during the last year, our present preliminary training for new engineers, including college graduates, consists of an orientation course only. This comprises a study of plant organization, structure, flow, techniques, and other fundamentals which enable the incoming employee to fit into the organization more quickly. The study of actual problems, lectures, and motion pictures illustrating shop methods and processes, are included for engineering draftsmen.

After original orientation, further training is gained by experience. Graduates are given ample opportunity for contact with manufacturing departments and for expanding their knowledge of plant methods and procedure. Under careful supervision, more responsible assignments, planned to broaden their technical knowledge, are made as rapidly as feasible. Under this system the majority of our engineering graduates progress steadily.

However, we have found that most engineering graduates are not sufficiently well-grounded in the fundamentals of our work, and we believe that, in the future, industry will expect the graduate to be better equipped with practical training before hire. Further use of cooperative systems, planned vacation work in industry, and more required practical courses would aid substantially in successful placement. Such preparation, which makes the graduate more immediately productive and reduces training time, is becoming an increasingly important consideration in employee selection.

Westinghouse Electric Corporation

All young mechanical engineering graduates take the Graduate Student Training Course consisting of the following:

1. Orientation—one week.
2. Several six- to eight-week basic work assignments in Westinghouse plants such as the Aviation Gas Turbine, Steam, Stoker, and Air-Conditioning divisions. There the engineer works in production inspection, and test departments, gaining a picture of the steps involved in the building and testing of equipment.
3. Eight 40-hour weeks of class work in fundamentals of Westinghouse engineering design and application. Conference leaders for each major type of apparatus under consideration are specialists in the design and application of that apparatus in their respective fields.
4. Men segregated to engineering department work then attend the Engineering Principles and Procedure School for two weeks. The subjects covered include the Functions of an Engineer in a Division, Westinghouse Drawing System, Manufacturing Information, Patents, Westinghouse Research Department, Technical Article Writing, Engineering Report Writing, Engineering Technical Societies, and Application Engineering.
5. A group of these men, selected by competitive examinations, attend the Westinghouse Mechanical Design School for a period of thirteen weeks. The subjects covered include Applied Mathematics, Theory of Elasticity and Strength of Materials, Dynamics and Vibrations, Fluid Mechanics, Thermodynamics and Heat Transfer. The young man is then given several six- to eight-week assignments in engineering departments leading to final placement.

Further opportunity for advanced technical training is afforded through the Westinghouse Graduate Study Program, offered in cooperation with several leading universities. Through this program, technical men at key Westinghouse locations may take evening engineering courses leading to Master's and Doctor's degrees.

Administrative Policies and Objectives of Research in Engineering Colleges*

By FREDERICK E TERMAN

Dean of Engineering, Stanford University

Research of the sponsored type, such as now available, presents a challenging opportunity for schools of engineering to advance the professional status of the engineer and of engineering. The opportunity lies in integrating such research properly into the teaching and training activities of a university, so that it becomes academic research

The objectives of academic research should be:

(1) The development of the highest type of trained men. In this connection one takes note of the fact that in the current shortage of scientifically trained personnel, nowhere is the shortage as severe as in the category of *engineer-scientist.*

(2) The further training of men already on teaching staffs. This applies to young men having real promise, but whose formal academic training is inadequate to enable them to realize their full possibilities as outstanding teachers and leaders in academic activities. This is of crucial importance because it is obviously impossible to train men in any substantial numbers to a level higher than represented by the training and knowledge of the teachers.

(3) Keeping faculty members interested in current progress, i.e., preventing them from going to seed.

(4) The advancement of engineering as a science and the raising of the professional status of the engineer This point is elaborated upon below.

(5) The advancement of knowledge This is placed last because it is an objective by definition, *i.e., if it is research it is advancement of knowledge.* In this connection it is to be noted that not all that goes by the name of research is advancement of knowledge.

Returning to Item (4), if the situation is realistically faced, we must agree that the present position of engineering in academic circles leaves much to be desired, particularly in schools having strong departments of natural sciences. Under such conditions engineering tends to be looked down upon as a necessary but not one of the higher activities. To use a mixed metaphor, among the sciences the social standing of the engineer is low.

Unfortunately, there is considerable justification for this situation, particularly in civil, electrical, and mechanical engineering, even though the situation is now rapidly improving. The length and breadth of systematic formal training, and the broad scholarly standards representing the minimum requirements that teachers of engineering must meet, are on the average considerably less rigorous than those required for corresponding academic positions

* Presented at the 54th Annual Meeting, A.S.E.E., Minneapolis, Minn., June 18–21, 1947.

in chemistry, physics, mathematics, biology, psychology, etc. In particular, although teachers of engineering are almost universally well grounded in the subject matter that they teach in *undergraduate* courses, they are far too frequently very inadequately trained in the fundamental science in which this subject matter originates. Again, only a very small percentage of the best engineering students, except those in chemical engineering, carry their studies far enough beyond the bachelor's degree to obtain a training comparable in depth and breadth with that received by the more promising young physicists, chemists, etc.

A review of the engineering developments of the war shows that the engineer failed in many ways to measure up to the needs associated with new fields of engineering activity. For example, in electronics the creative engineering that led to the remarkable array of new tubes, circuits, techniques, and systems that are the basis of the present boom in electronics, and likewise the establishment of the fundamental principles of engineering design and engineering analysis associated with these developments, originated in large measure with physicists who temporarily turned to engineering and took over leadership in radio engineering.

Perhaps this should not have been so, but an electrical engineer in the radio field could hardly have been expected to exercise leadership in these new developments that so profoundly changed radio. The typical good young electrical engineer in radio work spent four years in college, and concentrated a substantial part of his junior and senior years learning 60 cycle techniques and practices from professors who were not well versed in the more advanced mathematics and physics pertinent to radio engineering. Our young radio engineer normally had mathematics through ordinary differential equations, and had a few years of industrial experience in association with other similarly trained engineers. In contrast, the well trained young physicist of the same age had devoted seven to eight years to formal college training, knew mathematics through advanced calculus and complex variables, understood the fundamentals of electromagnetic theory which includes 60 cycle techniques, radio waves, etc., as special cases, and had acquired a working knowledge of optics, gas discharge processes, mechanics, thermodynamics, and the structure of the atom, all on a far more fundamental basis than the engineer's knowledge. A man with this type of training pitted against a standard electrical engineer of the same age and equal mental ability naturally won out every time in ability to understand new concepts and to develop their possibilities. Of course the physicist did not know engineering practice to start with, but he picked up what he needed to know very rapidly, whereas the engineer could not with equal ease acquire the basic scientific fundamentals that he lacked and needed so badly.

The situation that has been outlined is neither necessary nor desirable. In many fields of engineering, for example engineering mechanics, thermodynamics, fluid mechanics, and electronics, much of the technical knowledge taught in universities is very close to the basic sciences on which these fields rest. It is therefore desirable that the faculty members teaching these subjects, even in an elementary way, be thoroughly grounded in the related fundamental science, as well as in the application of this science to engineering problems. Perhaps the breadth of scholarship re-

quired of an engineering professor should be even broader than that of the physicist, certainly it should not be less.

It is also desirable that the ablest and more analytically minded young engineers, who in the future enter these fields of engineering either as workers in industry or as teachers, be thoroughly grounded in the pure science that underlies their engineering interest. This implies that these men should devote more than four years, and usually more than five years, to obtaining their training, and that in the more advanced stages of their training they be brought in contact with inspiring engineering teachers who really know their science as well as their engineering. This does not mean a fifth year added to the undergraduate program in order to crowd in still more undergraduate level work. Neither does it mean three years of relatively undirected research beyond a bachelor's degree. Rather it involves a *coordinated* program of *research* and *organized instruction* at the fifth, sixth and seventh year levels.

It may be felt on the part of some that carrying a substantial number of brighter men to these higher levels is a form of overtraining, in which men are equipped with knowledge that will not be used in most engineering work. I can see no more justification for this viewpoint than to argue that it is undesirable for a high school teacher of mathematics ever to have had analytical geometry and calculus on the grounds that analytical geometry and calculus are not taught ordinarily in high school. I cannot subscribe to the thesis that an engineer will be harmed by having been led to the top of the mountain and shown the whole field of knowledge that relates to his engineering interests.

Experience has shown that after leaving school men relatively seldom, and only with great difficulty, open up higher level fields of knowledge of analytical types that they have not previously been introduced to in school. In contrast, engineering practice is readily picked up on the job, often even without a college education. It therefore behooves us teachers to do everything possible to aid the more promising of our students to open as many doors as possible during the precious years that they are in school. We can never tell behind which door will lie the real opportunity for the individual.

The present time is unusually favorable for developing these higher aspects of engineering education, and for building up the scientific and professional position of the engineer both in academic circles and in industry. There are now a large number of engineering students carrying on graduate work who are adequately financed as a result of G.I. benefits. There is today a large demand for men possessing advanced training, in contrast with the pre-war situation when, for example, one of the very largest units of the electrical industry repeatedly stated that it *preferred* to employ men *without* any *advanced* training—the idea being to catch them young and bring them up in the way of the company. Another extremely favorable factor in the present picture is the large government sponsored research program now being carried on, in which the engineering schools of many universities are participating. As a result of these factors, engineering schools are now in a position to carry on advanced instruction and research at a higher level and

on a larger scale than ever before possible.

The administrative policies of research should be those policies that are necessary to accomplish the objectives discussed above. The important thing in the administration of research is to have clearly defined and worthwhile aims which are never lost sight of. In the final analysis, details such as overhead rates, methods of paying project supervisors, handling of inventions, business procedures, etc., although necessary, are of secondary importance.

In the administration of research we start with the fundamental fact that research is built around men, and that the most effective research programs are usually those carried on by "teams" involving an outstanding leader, often but not necessarily with one or two permanent or semi-permanent associates. The remainder of the team commonly consists of men who are in various stages of training. The research carried on by such a team is characterized by *continuity* involving a *long-range program* devoted to work on *important* and *closely related* problems. Effective basic research is not done by assigning problems to a staff member who happens to be free of commitments at the moment.

Sponsored research such as now available provides an unequalled opportunity for the establishment of effective research teams of the character described above. The financial assistance represented by sponsorship covers the cost of materials, provides the technician assistance required for efficient operation, assists in financing the key members of the team, and provides financial assistance where required by student members of the team.

One of the important values of an effective research team to an educational institution is that it provides a means by which young faculty members of promise can make up for the deficiencies of their original scholastic training. This is done by attaching such men to a team for a period of time, without sacrifice in total income, and under arrangements whereby a substantial fraction of their working time goes into the research and into related studies of the fundamental science pertinent to the research.

There are certain fundamental principles involved in the administration of research which must never be forgotten. First, the key men in any research group or team must be able to work directly on the programs themselves; they are lost to research if they become simply desk administrators of a research program.

Second, research requires leisure to think, *i.e.*, freedom from pressure. No ordinary man, however, brilliant and creative, can do himself justice if he is teaching three courses, must concern himself with the problems of 75 students who look to him as an advisor, and then be expected to put in half time on research. Third, one must not spread out thinly, but rather should concentrate on strength. The desirable plan for a typical department to follow is to build its staff and facilities over a long-range period with an eye to creating strength in only one or two specialties.

Finally, continuing vigilance is required to prevent the research program from degenerating into something else. Many like to play with technical things, particularly when plenty of money is available, but only a few can spearhead a productive research program. It is almost as easy for "research" to degenerate into puttering as it is for

water to run downhill. These dangers can be largely avoided by carrying out research as part of a carefully planned program that is closely directed by leaders of broad background who have already demonstrated a capacity for productive research. Poor results can generally be expected when inexperienced young men, however bright, are assigned to a subject and then turned loose to carry on "research" without the benefit of experienced guidance or example. Such people may deserve an A for effort, but they achieve a C in preparation for life work.

The successful realization of research objectives along the lines outlined will have a number of very important effects on engineering. It will first provide industry and government with a supply of highly trained men who will make a far more valuable contribution to the technological development of the country than these same men would make if limited to a standard four-year undergraduate training, or even a five-year training. It will also provide a pool of men from which universities can obtain staff members having the requisite scientific background and scholarly training required for leaders of new teams to keep the system growing and expanding. Vision and hard work are required on the part of engineering administrators to take full advantage of the present situation, and to use it to raise the engineering profession to a level where one has a true *engineering science* adequate to meet the needs of the country. It will among other things require that those of us in the administrative end of engineering establish standards for the qualifications and achievement for new staff members that are higher than we ourselves could possibly have met with the training, or rather lack of training, that we were able to obtain.

We must also get the best engineers on the university staffs, instead of letting industry have them. This may increase university expenditures for engineering, and it may result in engineering teachers receiving a higher level of remuneration than teachers of subjects that need not attract their men in competition with industry. None of us should be concerned, however, if engineering is able to achieve such a preferred position in an academic organization.

The war presented an opportunity for scientific achievement in engineering which the engineers were not able to take full advantage of. The present postwar era provides an opportunity to retrieve this situation for the future. It is doubtful if there will ever be another equally good chance. The engineering profession should and *must* take full advantage of the present opportunity. It is up to those directing the research activities in engineering schools to take the leadership that will lead to this result. It is in their power to make engineering a science of high degree, or they can let it become merely a vocation.

The Scope of Engineering Research*

By L. W. CHUBB

Director, Westinghouse Research Laboratories

This symposium on engineering research in college and industry should be very helpful in answering many questions regarding the supply, the desirable characteristics, and methods of seeking out and educating research personnel.

There is an ever increasing number of research and development engineers needed in industry. The late war and the general trend for several years has taught us that the life span of marketable products is becoming shorter and that improved devices, materials, and methods of fabrication are constantly demanded to conserve our national resources, off-set increasing labor costs, and supply better things at lower cost to a more discriminating public. This tendency has created sharper competition, and a relatively greater proportion of research, invention, and development activity in the engineering fields.

Industrial research is considered by some as one of our national resources and it is rapidly becoming almost an industry in itself. Back in 1920 there were only approximately 297 companies that maintained industrial research laboratories. The number and size of these laboratories has since then grown continually until today there is almost an eight-fold increase in twenty-six years. Recent figures comparing the magnitude of industrial research and the distribution of technical personnel will be of interest. These figures cover only *research in industry*. They do not include industrial research carried on in research foundations, at the universities, nor do they include government laboratories or the enormous research and development carried out by the Army, the Navy and other governmental institutions.

In industry alone the total number of laboratory personnel is over 133,000. Of this, the professional personnel numbers to about 54,000 and additional nonprofessional but technical personnel numbers 34,000. The 54,000 professional workers are divided as follows:

Chemists	21,095
Biologists	1,659
Engineers	20,637
Doctors of Medicine	236
Physicists	2,660
Metallurgists	2,364
Psychologists	22
Geologists	81
Other scientific professions (unclassified)	5,567

It will be noted that chemists and engineers stand out far in advance and I believe it might be said that over 90 per cent of all research in industry is really engineering research, or directed toward engineering application. In comparing these figures of the National Research Council with similar figures for 1940, we find an increase of approx-

* Presented at the December, 1946 meeting, Middle Atlantic Section, A.S.E.E.

mately 90 per cent in total personnel and an increase of about 45 per cent in professional personnel.

The addition of research foundation activities, regional laboratories, commercial laboratories and government research, all of which are relatively new, would swell these figures enormously and make a grand total of research activity several times that carried on just prior to the war.

A word regarding the Army and Navy research seems pertinent in this discussion as their extensive programs must draw technical personnel from the men trained in the colleges. The government fiscal program for research and development of all kinds is $1,613,-000,000. Eighty-four per cent of this is for the Army and Navy. The Navy part is required for the Bureau of Ships, the Bureau of Ordnance, the Bureau of Aeronautics and the Office of Naval Research, formerly known as the Office of Research and Invention. The *operating bureaus* spend their funds mostly on engineering development of weapons, apparatus and structures of all kinds for Naval use. The O.N.R., on the other hand, contracts for research of a more or less fundamental or basic nature which may give useful information for future application. Certainly this will result in a great deal of new knowledge and incidentally train many research workers.

The activities of O.N.R. started with an appropriation of $20,000,000, now raised to $45,000,000 and distributed roughly as follows: eleven million to naval laboratories, only seven million to industrial laboratories, and twenty-six million to university and college research. Forty per cent of this total is earmarked for nuclear physics, fourteen per cent for electronics, and the rest, forty-six per cent, for guided missiles, physics, chemistry, mathematics, and medicine. The total Navy program will require approximately eighty-one thousand research workers.

There is no corresponding Army agency like the O.N.R. Their research is to be carried out as specific tasks administered by the technical service commands and the Manhattan District.

For both services, a four-man board consisting of Dr. Bush, formerly Director of O.S.R.D., Dr. Condon, Director of the National Bureau of Standards, Admiral Lee representing the Navy, and General Aurand representing the Army, will coordinate the activities and decide which get priorities of equipment and trained men. It has been estimated that 45 per cent of all graduates coming from the colleges will be required for this work while government research and development continues at the contemplated level. Despite the present scarcity of graduate engineers, the program provides no direct action to locate and spur the training of scientists and engineers.

With all this increase in research, the addition of new research foundations, commercial laboratories and expansions in industry, the colleges are going to have a much greater demand for furnishing engineers suitable for research and development.

Engineering research which we are discussing today might be limited to that in the physical sciences directed toward engineering application in the industries, particularly in the electrical, mechanical, civil, and chemical fields. I might add that most of the national industrial effort is for engineering application.

We in industry classify scientific research as:

(1) Fundamental research which is carried on for the sake of obtaining new knowledge without having any specific application in mind. This prospecting, which we try to keep at a level between twenty and thirty per cent of the total, is done in fields which we believe most liable to give valuable knowledge for *future* application

(2) Basic research involving the same theoretical and experimental methods, but for the purpose of obtaining scientific data for application.

(3) Practical or specific research done to solve some problem, trouble, or engineering limitation of materials, process, or cost reduction which is of value for a particular application.

The third type of research might be classed as engineering development and is carried on cooperatively with the engineering departments who have the responsibility of the complete development of new products or new lines of products. There is no sharp dividing line between engineering research and development. We think of development as work usually carried on by experimental and test methods to obtain information for direct application. This may be done in the research laboratories where unusual equipment and men of special training are available, or in the engineering laboratories where there is engineering skill. Engineering development generally involves more than technical data. It involves design, competitive considerations, compromises in materials, dimensions, ratings, tooling, etc. This puts great responsibility on a development engineer, for he must exercise the best possible judgment in meeting commercial requirements, costs, and performance specifications, sticking closely to standards, but not necessarily to the optimum design for each individual product. To meet this responsibility, the development engineer needs research information in ever increasing quantity

In the larger industrial companies, research is usually set aside from the various engineering departments, responsible for design and development of the product. However, very close cooperation is maintained between the laboratories, engineering and production departments.

The centralization of research precludes the necessity of duplicating unusual facilities and specialists in the various fields of science and engineering. Centralization also has the advantage of providing a clearing house and source for the dissemination of new knowledge. Data obtained for or in one engineering department may find multiple application in other plants.

Research and technology is becoming so complicated and extensive that it is following the same pattern as the family economy. We no longer depend upon the genius to invent, develop and make, for the market, products which involve work in several fields of science and engineering, any more than we depend upon the family unit to be self-supporting by making their own shoes, clothes, supplies, or raising their own food for sustenance. Teamwork of specialists all adding their part to an ambitious undertaking is the only practical method of meeting the modern call for new advances in technology. The industrialist *must* provide facilities and depend upon cooperative contributions of men trained in research, engineering, and production.

Now in addition to the cooperation of men trained in different fields, there must also be good cooperation of men having different characteristics, but trained in the same field or branch of engineering.

A research or development engineer should be imaginative, a critical observer, dissatisfied with things as they are. He should be a creative thinker, inventive, have good technical ability, good judgment, preferably an aggressive individual with lots of initiative.

The men you educate need not necessarily possess all of the foregoing attributes to a high degree, for they can be useful in research when teamed with others having the supplementary characteristics.

There are certain qualities, however, which must be possessed by all research workers. They are, in order of importance: cooperativeness (ability to get along well with fellow workers), honesty, patience, and a good fundamental training in the physical sciences and engineering branch pertinent to their chosen activity.

Frequently a good team for a project will consist of the creative thinker, or inventor, who may be a poor experimenter or planner, an aggressive worker who likes to carry through the ideas of others, and perhaps other teammates who supply additional functions needed to bring a project to an early and successful conclusion.

This method of using men brings up a question of individual training. Should they be educated to play any position on the team, by endeavoring to reduce their deficiencies, or should they be developed for higher proficiency along lines in which they show a natural aptitude?

These are questions best answered after graduation. In college, we believe emphasis should be placed on fundamental courses. Specialization and development of natural aptitudes will come with experience after employment in industry and the correction of deficient personal characteristics will often come through the teamwork with others.

Engineering Principles in Biophysics

By KARLEM RIESS
Assistant Professor of Physics Tulane University

Biophysics is that branch of applied physics which utilizes the principles and techniques of physics for the investigation of biological and medical problems. This is accomplished through the application of facts and tools of engineering, chemistry and medicine. Modern biophysics includes such topics as the study of the physics of living organisms, the utilization and application of X-rays, radioactivity, ultraviolet and infrared light, spectroscopy, surface phenomena, membrane studies, problems of nerve conduction, the application of physics to body mechanisms, and the use of research aids such as the ultra-centrifuge, the electron microscope and the mass spectrograph. While these may seem to be unrelated subjects, all are linked to the general theme—the explanation of a biological effect by means of a physical principle In each of the subdivisions mentioned above, we find applications of basic engineering principles and materials Some of these will be discussed in this paper.

The generation and use of X-rays is as familiar to engineers as to physicists. Widespread applications of X-rays in routine medical diagnosis, in X-ray diffraction and in many industrial installations have taken place in the past few years. The biophysicist uses X-rays for radiation therapy and to produce changes by irradiation. Studies of the nature of chromosomes and of mutations have been of great value in our efforts to understand the living plant and animal cell. The engineer uses a portable X-ray unit for metallographic inspection, and follows safety requirements set up by the biophysicist. The measurement of transmitted radiation through various thicknesses of lead resulted in the manufacture of protective gloves, gauntlets and aprons of rubber impregnated with lead oxide. These serve as adequate protection for most of the smaller installations. Concrete is also used as a protective material. A concrete barrier of thickness 26.5 cm. will shield the operator from 400 kilovolt radiation.

If the operator of an X-ray unit is subjected to irradiation, the safe or tolerance X-radiation dosages have been established. The biophysicist has found that the body cells which are most sensitive to X-radiation are those of the reproductive organs, bone, muscle and skin. Brain and nerve cells are among the most resistant.

Biophysical studies of X-rays have led to the extensive development of fluorescent screens. These are accepted as fundamental components of engineering apparatus, such as the cathode ray oscillograph.

The methods of the chemist and chemical engineer are combined in the field of applied radioactivity. The

quantity production of radium salts from natural ores requires many of their industrial techniques. The extraction and purification of radon gas in semi-automatic stills is another example. The biophysicist then uses the end products, the radium and the radon, for tissue irradiation, for the bleaching of butter, for investigation of necrosis conditions, and to study the rate of cell growth and repair.

The cyclotron, betatron and synchrotron are engineering as well as physical achievements. The older and more familiar cyclotron whirls positive ions in ever increasing circular paths between the poles of a magnet. The ions are thus given an increasingly high velocity and may be used for the bombardment of materials. A source of high energy projectiles is thus available for the transmutation of chemical elements. Many of the nuclei after transmutation are artificially radioactive. These are the tracers for many biological experiments.

The betatron is an electron accelerator, often called a glorified doughnut. Electrons are rotated in a circular path, acquire high energy, and when they strike metal targets produce X-rays corresponding to one million volts.

The synchrotron is the newest and most compact type of electron accelerator. The electrons are speeded up as the magnetic field increases, and, in the presence of an oscillating electric field, revolve in groups. The electrons may be directed against a target and X-rays produced. The commercial units produce seventy million volt X-rays, and units up to three hundred million volts are under construction. The advantages of this accelerator over the betatron is its small size and low weight. The commercial development of these three accelerators would have been impossible without the engineer.

The radioactive tracers produced by the cyclotron, and also by the atomic pile procedures, are extremely valuable in biophysics. Examples are the use of carbon-14 in metabolism studies, of sodium-24 in fluid circulation in plants, of phosphorus-32 in bone studies, of iodine-128 in the study of thyroid deficiencies, of thorium B-212 in the estimation of blood volume, and the many experiments, as yet inconclusive, on the use of tracers in the study of cancer. The petroleum engineer uses radioactive materials to map oil pools. The metallurgist uses tagged phosphorus compounds to trace phosphorus in steel refining. Heavy hydrogen or deuterium atoms are used in cracking processes and in the hydrogenation of oils. All of these and hundreds of others would have been impossible without the engineering techniques which enter into their manufacture.

The illuminating engineer has developed many new types of commercial and home lamps. The biophysicist is interested in all of these, particularly the mercury vapor lamps, the many varieties of sunlamps and the sterilamps. The effect of ultraviolet radiation on the skin has been extensively studied. It has been found that the tanning of skin is a photodynamic action in the presence of oxygen, and is largely due to the oxidation of pigments in the skin in a reduced, colorless state. These pigments include melanin, melanoid and carotin, commonly found in carrots.

The bactericidal action of the sterilamps is due to ultraviolet radiation principally in the 2537 Angstrom region. The transportation of pathogenic bacteria through air to a wound has been greatly reduced by sterilization

of air in operating rooms. Sterilization of water with ultraviolet has been found feasible only if the water is treated in layers less than 2 cm. thick and if the flow is moderate.

Use of ultraviolet sources for irradiation of edible materials is of increasing industrial importance. The sterols become antirachitic on irradiation. The absorption of ergosterol disappears with irradiation, but activation yielding vitamin-D results.

The commercial photronic or barrier-layer photoelectric cell finds application in many biophysical instruments. For example, the Kuder colorimeter measures calcium or phosphorus in blood, albumin in urine, hemoglobin, sugar in blood or urine, and urea nitrogen.

One of the most interesting fields of biophysics is that of nerve conduction. A nerve is composed of many separate fibers. Each fiber is comparable to a well insulated wire, with the insulation squeezed in at regular intervals for some, and removed completely for others. The insulation corresponds to the medullary sheath of myelin and the bare wire to the axon of the nerve. These fibers vary in length. There is a difference of potential across the surface of the living fiber. This, curiously, disappears when the nerve is deprived of oxygen. The axon of the stellar nerve of the giant Atlantic squid has been used in many experiments.

A nerve fiber is equivalent to a resistance-inductance-capacitance series circuit, with applied direct electromotive force. Differential equations for the propagation of current along the axon have been set up and solutions obtained. The longitudinal and transverse impedance of the axon during stimulation was measured using a Wheatstone bridge with amplifier and cathode ray oscillograph over a range from 30 cycles to 200 kilocycles per second. There is associated with the nerve fiber a monophasic action potential. This is a wave of activity along the nerve following a stimulus and is a negative pulse of maximum five millivolts. There is also a change in membrane potential during current flow. The membranes display both inductive and capacitative reactance, while the axoplasm and connective tissues function as resistances. The passage of a stimulating impulse along a nerve fiber may be detected with silver-silver chloride-sodium chloride nonpolarizable electrodes in contact with the surfaces of the nerve. In the myelinated fibers the impulse speed may be as high as one hundred meters per second; in the unmyelinated, as low as one meter per second.

Nerves of the squid are not the only cells used in these experiments. Cells of the plant *Nitella* give the same results. There are also action potentials and excitation conduction in smooth-muscle fibers. The smooth muscles of the visceral organs show a brief action potential on contraction. Smooth muscle activity is thought to be due to the discharge of impulses by action potentials.

In many plants and trees there are inherent electromotive forces. For example, in Douglas fir trees an electromotive force is set up between one electrode in the center xylem tissue and one at any point on the outer surface. Such data are being used to study the upward and downward conduction of sap in the xylem and phloem cells of the plant.

A fundamental law in mechanics is Newton's second law of motion. The mathematical formulation of this law

in terms of the time derivative of velocity is well known. An analogous relation may be set up between the time derivative of an excitation and an applied stimulus. All of the procedures of theoretical mechanics may then be followed for the excitation equation. Unfortunately the experimental stimulation of nerve fibers with alternating currents does not exactly follow the desired theoretical results.

Electronic devices are of great importance in biophysics. Mention has been made of the cathode ray oscillograph as a detecting device. Various types of amplifiers, oscillators and control units find wide application. In the building of a mass spectrograph for the identification of isotopes the control unit is composed of several types of amplifiers. Amplifiers and oscillographs are used with Geiger counters. The electroencephalograph for the study of brain pulses and brain patterns uses two amplifiers, several filter circuits and a mechanically recording oscillograph.

A familiar illustration in mechanics is that of the coupled oscillator, which may be pictured as two identical pendulums coupled together by a spring. Two of the small bones of the middle ear, the malleus and the incus, function as a coupled oscillator. Vibrations impressed on the malleus are transmitted to the end of the incus exactly as energy is transferred from one of the coupled pendulums to the other.

All of the fundamentals of acoustical engineering are utilized in auditory biophysics. The decibel scale of measure, loudness measurements, noise meters, pitch, and hearing thresholds have been studied from the point of view of the physics and physiology of the ear. Measurements of aural harmonics have been made by observing the fluctuating electrical potential set up in the cochlea of the inner ear by pressure disturbances which cause the eardrum to impress motion on the cochlear fluid and thus generate the potential. The frequencies are measured by means of a vacuum tube wave analyzer.

Related to this is the hydrodynamic theory which treats the cochlea of the ear as a hydraulic tunnel with an elastic wall, a selective response mechanism and a large damping factor. In engineering terms this would follow the analysis of a hydraulic system contained in a cylindrical vessel, with elastic walls and a pressure disturbance propagated along the walls. The mathematical analogy here is quite satisfactory.

Mention should be made of the microscope and the electron microscope as valuable tools in biophysics. The engineering principles in the electron microscope are numerous and familiar. The electron microscope is finding wide application in the study of virus diseases, identification of viruses, and in the study of the mechanism of cell division.

There have been studies with ultrasonic vibrations for depolymerization of starch and gelatin. These vibrations have been used to break down the protein hemocyanin obtained from the edible snail *Helix pomatia*.

These rambling examples are but a few of the many possible applications of engineering principles and techniques to biophysics. The coming years will bring the engineer, the physicist and the biologist closer together for the solution of mutually interesting problems in the border field of applied biophysics.

The Naval Reserve Officers Training Corps Program in the Engineering Colleges

By J. H. BELKNAP
Chairman, Division of Engineering, University of Rochester

The Holloway Plan as authorized by Public Law 729 has established NROTC units in 52 colleges and universities. The training offered in these units is designed to provide "a steady supply of well-educated junior officers for the line and staff corps of the Regular Navy and to build up a reserve of trained officers who will be ready to serve their country at a moment's notice in a national emergency" The plan supplements, in point of numbers, the program offered by the Naval Academy.

The arrangement provides for commissioning and granting of baccalaureate degrees to those who satisfy the requirements set up by the Navy and the colleges

This paper has to do with the integration of the regular and Naval programs in the engineering colleges and is based upon a survey just completed. It is inspired by the problem which is brought to the engineering colleges by the addition of 24 Naval Science course credits to an already crowded engineering curricula. The study deals only with undergraduate curricula in engineering as offered by the concerned colleges.

In the preparation of this paper full use has been made of the information in the hands of the Association of 52 Colleges offering the NROTC programs Dr. Alan Valentine, president of the Association, has indicated his interest in the study. Data obtained through the use of the questionnaire of May, 1947 will be made available to the Association for their analysis with respect to the combination of Navy courses and engineering curricula.

Thirty-four questionnaires have been completed and returned. The students involved total 3,310 of which number 1,585 or 48 per cent are following engineering curricula.

It is known that of the 34 colleges replying, 32 offer the B.S. in particular engineering fields at the end of 4 years of successful undergraduate preparation. Two are following the 5 year plan.

Of the 32 colleges offering the B.S. degree in 4 years, 19 will provide both degree and commission in 4 years; and of the entire group, 17 will require additional time up to 10 semesters or 5 academic years for both. Six colleges offer the Bachelor of Naval Science Degree, or the B.S. without designation, and commissions at the end of four years and will require additional time for the engineering degree.

The great majority of the institutions interrogated offer full 24 credits for the Naval Science courses. Space is

made available for the additional 24 credits in Naval Science by the omission of courses in the humanities and social sciences and courses in engineering electives. In no institution replying is it known that Naval Science courses are substituted for the physical sciences and mathematics. In only one or two instances are "regular" courses in engineering set aside to make room for the Naval Science courses, and in those cases it is understood that all essential courses have been retained.

Of the 19 colleges offering both the B.S. degree and commission in 4 years, 16 are satisfied with the arrangement. Of the full group of those who indicate lack of satisfaction with the plan as now used, only 7 propose that betterment would be achieved if the plan were to be extended. Of the total group of the 34 colleges, 9 propose that the combination courses in engineering and Naval Science be extended to 10 semesters (5 academic years) and one proposes 9 semesters and a summer session. An additional 8 suggest some extension but do not indicate how long the extension should be. Accordingly 18 out of the 34 favor a lengthening of the combination program beyond 8 semesters or 4 academic years. This, to repeat, is in contrast with the 16 colleges in which there is satisfaction with the 4 year plan.

Some of the answers indicate "satisfaction" with the 4 year plan and yet propose an extension beyond 4 years! From this and several other observed disagreements it may be understood that the problems are not yet happily resolved and that changes may be viewed with favor.

To summarize certain of the findings, it is apparent that all who answered the questionnaire analyzed their curricula in terms of the following breakdown:

SAMPLE COMPARISON

TYPICAL MECHANICAL ENGINEERING CURRICULUM

REGULAR NROIC

ECPD Basis (Cr. Hr.)	Subjects	Regular (Cr. Hrs.)	NROIC (Cr. Hrs.)	Courses Dropped
40.4	Mechanical Engineering	38	30	6—Eng. Elect. 2—Surveying
20.6	Other Engineering	16	16	None
10.9	Mech. and Hydraulics	14	14	None
5.9	Graphics	8	6	2-Shop Drawing
2.9	Shop	3	2	1-Foundry Lec.
15.6	Physical Sciences	16	16	None
18.9	Mathematics	14	14	None
15.1	Arts (Humanistic-Social)	24	24	None
4.2	Phys. Training	4	4	None
5.5	Non-Engr. Electives	6	0	6—all as selected
0.0	Naval Science Courses	0	18*	Added
		143	144	

* Eighteen rather than 24 N.S. credits required because Navy agreed to waive N.S. 401 and N.S. 402.

A STUDY OF THE NAVAL RESERVE OFFICER TRAINING

No	(1) NROTC Students in Unit			(2) Time Required for 'Regular' B S Degree in Engr Field		(3) Credits Authorized for N S Courses	(4) Credit Hours Dropped to Provide for N S Courses			(5) Naval Science Courses Waived by Navy
	Engr.	Arts and Other	Total	4 years	5 years		Humanistic	Reg Engr	Engr Elect	
1	35	19	54	x		24 (in equiv qtr crs)	18 qtr crs	0	12 qtr crs	None now, but anticipated
2	103	49	152	x		18 in Engr 20 in Arts	12	0	6	None
3	50	50	100	x B S in N S		24				None
4	61	32	93		x	24 (not all depts)	0	0	0	
5	66	95	161	x		24	22	0	0	N S 402 (modified to 1 sem course)
6	167	0	167	x		30 qtr.				None
7	13	95	108	x		24				N S 401 and 402 (?)
8	81	4	85	x		24	9	9	6	None
9	65	87	152	x		24 for some			?	None
10	70	23	93	x		24			16/18	?
11	27	27	54		x	33 qtr c	15		15/3	N S 411 and 412 (on recommendations)
12	95	87	182	x		24	6	0	6	Next year?
13	25	16	41	x		24				None now but anticipated
14	5	21	26	x		24				None
15	10	31	41	x		24				None
16	14	31	45	x		24				None
17	38	103	141	x		24	27 qtr hr	9 qtr hr		None
18	29	42	71	x		24	12	6	6	None
19	22	31	53	x		24	3 qtr hr.	3 qtr hr	30 qtr. hr	None
20	40	45	85	x		24	?		?	None
21	43	178	221	x		24	15	0	3	N S 401 and N S 402
22	?	?	?	x		24	6	0	6	None
23	101	5	106	x		24	6	0	3	N S 401 and Part N S 402
24	21	10	31	x		21	?	?	?	N S 401
25	55	43	98	x		24	6 (?)	5	6	N S 401 and N.S 402
26	37	43	80	x		24	?	?	?	None
27	49	30	79	x		24	6	8	10	None
28	11	85	96	x		24	?	?	?	None
29	46	61	107	x		12 hrs	?	?	?	None
30	32	54	86	x		24	?	?	?	None
31	11	12	23	x		24	?	?	?	N S 213 411 412
32	38	53	91	x		?	?	?	?	None
33	65	60	125	x		12	?	?	?	None
34	60	203	263	x		24	?	?	?	None
	1585		3310							

(a) Physical sciences and mathematics
(b) Required engineering subjects
(c) Humanistic and social studies
(d) Engineering electives.

It is definitely established that the first two groups may not be reduced but that there is some flexibility in the last two All colleges reporting on present and contemplated operations based upon a plan for graduating and commissioning within a four year period have made adjustments with the (c) humanistic and social studies group and the (d) engineering elective group. By and large the subjects listed within all engineering curricula quite uni-

COURSES IN 34 COLLEGES AND UNIVERSITIES

No	(6) Time Required to Obtain both Degree and Commission		(7) Is Present Arrangement Satisfactory?		(8) Courses which Substitute for Those Waived by Navy (See column 5)	(9) Recommendations to Extend		(10) Proposals
	4 years	5 years	Yes	No		Yes	No	
1	x			x		x		Extend
2	x			x		x		Ex. to 9 or 10 Semesters
3	B.S. in N.S.	Both		x			x	
4		x	x		H.P. and E.E.		x	
5	x		?				x	Provisional Arrangement
6	x		x					
7	x			?	Approp. E.E. and/ or Steam Courses		x	
8	x		x				x	
9	B.S. in N.S.	Both	x			x		Ex. to 10 Sem.
10	x		x					
11		x 14 qtr.	x		Humanistic and Elect. Engr. Courses		x	
12		9 sem.+ Sum. Session		x		x		Ex. to 9 Sem. and Summer Session
13		4+2 qtrs.		x		x		Ex. to 10 Sem.
14		4+Sum S.	x			x		Ex. to 10 Sem.
15		x	x			x		Ex. to 10 Sem.
16		x	x	?		x		Ex. to 10 Sem.
17	x		x				x	
18	x		x?			x		Ex. to 10 Sem.
19	x		x				x	
20	x		x			x		Ex. to 10 Sem.
21	x		x		Seminar to cover ship const. and damage control		x	
22	x		x			x		Extend
23	x		x		Any equiv. H.P.		x	
24	AB	B.S.		x	Crs. in M.E., Ch.E., etc	x		Extend
25	x(?)		x		H.P. and other approp		x	
26	B.S. in En.	B.S.	x			x		Extend
27	x		?			x		Change needed
28	B.S.	Both		x		x		Extend
29	x or 9 Sem.		x					
30	x (with overload)		x				x?	Ex. to 10 Sem.
31		Both		x	E.E. Courses	x		Extend
32		Both	x			x		Extend
33	B.S. in N.S.	Both	x				x	Extend
34	x B. of Engr.		x				x	

formly aggregate 140 semester hours for graduation with the baccalaureate degree.

In reading the notes found on the questionnaires and the letters transmitting the questionnaires I have found opinions varying from the one extreme of holding quite inflexibly to a rigid requirement within all engineering curricula to the other which says in effect "we can still hold to sufficiently rigorous requirements and provide both degree and commission in 4 years." A fine indication of patriotic interest has been shown in the replies to the questionnaire.

Some of the colleges report that they have given certain of their required

courses a "Navy Slant" and that the Navy in return has granted that such courses may substitute for the comparable Naval Science courses An example of such economies is that of the substitution of heat power and electrical engineering courses for the more advanced Naval Science courses. In these cases the reasons for the substitutions are apparent, but in other course comparisons it is not so easy to see the similarities. Possibly the Navy will be able to make adjustments toward the "standard" courses and the Colleges will be able to give their regular courses a "Navy flavor" through the use of examples taken from Marine practice, thus working toward a more nearly common requirement.

By the same token the colleges might well recognize the benefits to be had through the taking of N.S courses If, for example, 9 credit hours in the humanistic and social studies and 9 credit hours in engineering electives are set aside to provide for 18 Naval Science course credits, not all is lost! Specifically, an E.E. student might be required to drop 3 credit hours of engineering elective in plane surveying so as to be able to adjust his schedule to include the required N.S. courses. As a compensation for that loss there would be comparable information in the Naval Science courses in navigation and fire control (gun pointing) and in certain respects he would find a more exact use of engineering principles in the Navy courses.

The Navy is in need of college trained engineers and our institutions should assist in every way possible in providing for that need. It is a privilege for the colleges to serve our Nation through the Navy, and our obligation with respect to national defense should not be minimized. The colleges consider it an honor to be selected to aid in the training of those who are to serve in peace and who may be called upon to defend our country in time of war.

The Army and Navy know the importance of engineering education Without our engineers and their place of work — the country's industries — the war could not have been brought to its successful end How close was the race is known to many of us The world knows and acknowledges the importance of engineering education and its product, our young engineering graduates, and the Army and Navy must have their share of the output of the engineering colleges Therefore our efforts to integrate the needs of industry with the requirements of the armed forces must be effective.

It is significant that we have gotten under way in this important cooperative action involving the Navy and the Colleges, on the basis of the integration of established plans, and with the least amount of disruption of the accepted standards of engineering education It is evident that we recognize fully the seriousness of the recent world conflict, the need for preparedness, and the continuing threat to world peace. The spirit of give and take has been shown and with the attitudes found in both the Colleges and the Navy the problems remaining will indeed be resolved with satisfactory results.

We should not permit our engineering programs to be reduced in their essential content, and the humanistic and social studies should be retained insofar as is possible. But it is to be recommended that we realistically view the need that our nation maintain its military strength, not for the purpose of waging war, but, through actual military superiority, to prevent war. The

Naval Science courses of engineering type are broadening and also provide an insight into another use of engineering principles. It is right that the Naval Science courses be given full credit and it is fair, too, that they be acknowledged as the equivalent of certain of the more general courses.

It is proposed finally that the Navy, as in this instance, be acquainted with our problems and our determination to serve the armed forces and that the Navy consider the possibility of modifying its in-residence courses to the point that more substitutions may be made. Such changes may necessitate covering more subjects while the students are on cruise. The colleges also should attempt to put in their regular engineering courses, where possible, material of particular interest and use to the Navy. The colleges' obligation should be that of providing the best possible arrangements such that graduation and commissioning may be accomplished in four years, or the shortest possible extension of time beyond four years The final alternative is to go to a five year plan and hold to all present requirements.

Correlation of Mathematics and Electrical Engineering *

PART I

By H. K. JUSTICE

Assistant Dean, College of Engineering, University of Cincinnati

Correlation, in the sense in which we are here interested, is a difficult term to define. Whether it should include the mere arrangement of courses in logical sequence is open to question. Some of you may regard the essential requirement of basing each course on carefully planned prerequisites as too fundamental to be classified specifically as correlation. Nevertheless, some reference to the sequence of courses seems inevitable in any discussion of correlation. There should be no need, however, to dwell on this aspect of the subject. All of us know that any curriculum, once established, demands a rather inflexible arrangement of courses.

What I shall have to say will deal with basic courses of the first two years of electrical engineering at the University of Cincinnati. Professor Restemeyer will then develop the subject of correlation in more advanced courses. Professor Restemeyer and I do not in any sense wish to display the Cincinnati plan before you as a model. On the contrary, we present it humbly for whatever merits it may have, in the hope of soliciting frank and constructive criticism.

In the year 1920 the functions, personnel, and scope of the department of mathematics at Cincinnati were greatly expanded. At that time all basic courses of the first two years in statics, dynamics, drawing, and descriptive geometry were placed under the jurisdiction of the mathematics department, as also were courses of the upper years in technical mechanics, strength of materials, indeterminate structures, and (later) vibration problems. The chief purpose of this reorganization was to effect a comprehensive correlation of these subjects with mathematics and with each other. Throughout the period of more than twenty-five years, during which this plan remained in effect, constant attention has been given to the question of correlation. For reasons which I shall presently discuss, a separate department of engineering drawing has recently been established and, for the most part, members of the mathematics department no longer teach drawing.

Our freshman curriculum for all engineering students includes algebra, trigonometry, analytic geometry, statics, descriptive geometry, drawing, and

* Presented at the Annual Meeting, Minneapolis, June 18–21, 1947.

vector algebra. Vector algebra, which is offered during the third and final term of the year, includes studies of the scalar and vector products and the scalar triple product, with applications to statics and to space analytic geometry of the point, line, and plane. All these subjects have been handled by the department of mathematics. The freshman program includes also general inorganic chemistry, English, metallurgy, and coordination. To accomplish as high a degree of correlation as possible among those subjects handled by the department of mathematics, proper course sequences are maintained, assignment schedules are carefully prepared in mimeographed form, and all instructors are required to follow the same schedule of topics in each course.

Technical courses of the first two terms of the sophomore year in electrical engineering are as follows: calculus, dynamics, physics, engineering materials, engineering drawing, coordination, and English. At the beginning of the third term all sophomores are turned over to the department of electrical engineering for the following courses: graphical applications of mathematics, electric and magnetic fields, applied kinematics, kinematic drawing, elements of circuit analysis, and elementary electrical laboratory. The last-mentioned course includes the study of direct and alternating current metering, direct current bridge circuits, single phase circuits, and flux measurement. Calculus and physics are continued through this term.

The following outline reflects the correlation which has been accomplished at Cincinnati among freshman courses and courses of the first two terms of the sophomore year in electrical engineering.

Freshman Year

I. *Correlation of Drawing with Statics, Descriptive Geometry, Algebra, Analytic Geometry, and Vector Algebra.*

Problems involving the following topics are worked in the drawing room. Different data are assigned to the various students.

1. Resultant of concurrent, coplanar forces by use of the force polygon.
2. Resultant of nonconcurrent, coplanar forces by use of the funicular polygon.
3. Resultant of concurrent, noncoplanar forces by projection on perpendicular planes of reference and subsequent true-length determination of resultant by descriptive geometry.
4. Resultant of parallel forces in space by use of the equilibrium polygon applied to two views. Determination of centroids of areas by similar means.
5. Elementary equilibrium problems by use of the force polygon.
6. Equilibrium of coplanar, nonconcurrent forces by use of equilibrium polygon.
7. Reactions in the three-hinged arch by superposition of effects caused by forces on the separate parts of the arch.
8. Stresses in framed structures by the use of the Maxwell Diagram.
9. Three-dimensional, concurrent forces in equilibrium. The tripod problem and others requiring revolution or auxiliary projection for true-length.
10. Pin reactions in various structures with bending members.

11. Point of intersection of three planes represented by given cartesian equations Algebraic check.
12. Perpendicular distance from a plane to a point from data in cartesian form. Analytical check by vector methods.
13. Perpendicular distance between two nonintersecting lines from data in cartesian form. Analytical check by vector methods

II *Correlation of Vector Algebra with Analytic Geometry and Statics*

1 While the course in vector algebra is intended primarily to furnish the background for vectorial mechanics and electrical engineering courses, correlations are established with analytic geometry and statics in problems of the following types:

a. Point of division
b. Standard problems in space analytic geometry of the point, line, and plane, such as were mentioned above under I.
c. Moment of a force about a point and its use in determining the moment about an axis

Sophomore Year—Electrical Engineering

I. *Correlation of Calculus, Dynamics, and Physics.*

1. Calculus and dynamics are handled by the department of mathematics and are taught concurrently with physics.
2. Each instructor has the same students in both calculus and dynamics. The theory of dynamics is taught from the vector standpoint.
3. Integration is introduced early in the calculus course to provide a tool for mechanics and physics. This makes possible the inclusion of a great variety of motion problems in kinematics, as for example the projectile problem from the standpoint of integrating acceleration components
4. Harmonic motion (from both the kinematic and kinetic points of view) is treated in dynamics and omitted from calculus.
5. Related rate problems are studied in calculus and are concurrently treated in dynamics from the standpoint of velocity components, relative velocity, or instantaneous center, and the various solutions are compared A typical elementary example is that of finding the speed of the upper end of a ladder whose base is moved at a specified rate.
6. Because statics and dynamics are offered as separate courses in the first and second years, respectively, relatively little time is devoted to these topics in physics The time thus saved in the physics course is devoted largely to electricity and magnetism.
7. Hyperbolic functions are covered rather thoroughly in the calculus course and their relation to trigonometric functions is emphasized

II *Correlation of Sophomore Drawing with Mathematics and Electrical Engineering*

1. The first term of sophomore drawing includes technical sketching and assembly drawing of electrical equipment. Air-gap variable condensers of the Johnson type are used as models.
2. The second term of sophomore drawing includes a study of empirical equations by the method of averages and the method of

least squares. In order that the student may gain familiarity with electrical terminology and phenomena exclusive used is made of experimental electrical data.

3. The third term of sophomore drawing (called graphical applications of mathematics) deals with scales and scale moduli, alignment charts, and graphical differentiation and integration.

I should be remiss if I failed to inject a word of warning on the danger of carrying correlation too far. Some of you may already have detected shortcomings in the program which I have outlined. The principal fault as we see it lies in freshman drawing. In our eagerness during past years to incorporate in drawing a high degree of correlation with other courses of the freshman year, some of the essentials of pure mechanical drawing were sacrificed in favor of graphical problems involving algebra, analytic geometry, statics, and vector analysis. As a result of this practice, it was found that students who were placed on co-op jobs in drafting rooms were found to be deficient in some of the mechanical aspects of drawing. Steps have recently been taken to remedy this situation. The remedy, of course, consisted in restoring those essentials of drawing which had previously been deleted.

Another difficulty which has been recognized at Cincinnati is of an administrative nature. I have indicated that engineering drawing was formerly under the jurisdiction of the department of mathematics and that recently a separate department of drawing has been created. The principal reason for this change is that under the original plan of requiring members of the mathematics department to teach both mathematics and drawing, considerable difficulty was experienced in locating men who were fully qualified in both fields and who were also willing to teach drawing. The obvious answer to this was to create a separate department of drawing. Fortunately, the head of the new department is one of our experienced teachers in mathematics whose inclination is still to preserve all the correlation possible between drawing and other subjects.

Before closing I should like to say a word in favor of a problem course, preferably in the sophomore year with calculus as a corequisite, in which the student is called upon to solve assorted problems from the various fields of engineering and science. About ten years ago I had occasion to develop such a course for a group of sophomores in general engineering, and to teach it for several years prior to the recent war. The results convinced me of the importance of a course of this kind in developing the skill of the student, in demonstrating the utility of mathematics as a scientific tool, and in furnishing an excellent means of correlating the subject with various branches, or with some particular branch, of engineering. In this connection your attention is called to a relatively recent book entitled "Engineering Problems Illustrating Mathematics," which has been sponsored by the Mathematics Division of A.S.E.E. and was prepared by a committee from this division under the chairmanship of Professor John W. Cell. The book contains a large number of problems, many of them from electrical engineering, and seems to be well suited for a problem course in which mathematics through calculus is correlated with engineering.

I wish also to emphasize the need for close liaison between departments in the teaching of engineering and science subjects. Especially is this necessary where two courses are being taught concurrently by separate departments and one of the courses is dependent on the other, as in the case of physics and calculus, calculus and dynamics, or dynamics and physics. Pains should be taken to arrange both courses in such a way that each assignment is based exclusively on material previously covered.

Not only does the careful correlation of courses exhibit the interrelationships of various fields of science and engineering, thereby increasing student interest, but also it affords the opportunity of reiterating basic concepts. It is a well-known pedagogical principle that a student learns by repetition. Let us offer him the best means to his learning.

Part II

By William E. Restemeyer

University of Cincinnati

An electrical engineering student when asked about his technical courses replied that they contained many different topics, all of them mathematics in one form or another. Of course what he meant by this remark was that the fundamental laws of electrical science are expressed in mathematical language because they involve relations between the measures of physical quantities. It therefore becomes necessary for those interested in science to be able to understand this language and to use it.

It is the combination of scientific experience and familiarity with the techniques and results of mathematics which has produced the technological wonders of our present day world. The past ten years has brought about a tremendous increase in the scope of electrical engineering and thereby a strong need for revisions in electrical engineering education programs. Noteworthy examples of this trend may be found as early as 1942 in the paper of Professor Bewley [1] in the January issue of the Journal of Engineering Education, and that of Professor Guillemin [2] in the March, 1945 issue.

The accompanying need for improved correlation between mathematical and electrical engineering courses in the educational structure has already been well stated by Dr. Brennecke. Dean Justice has told you of correlation of mathematics and mechanics in the freshman year and first two terms of the sophomore year at the University of Cincinnati. With minor exceptions, this correlation is common to all engineering students. In the third term of the sophomore years the elec-

---

* Presented at the Joint Meeting of the Mathematics Division and Electrical Engineering Division, at the Annual Meeting of the A.S.E.E., Minneapolis, June 18–21, 1947.

[1] Bewley, L. V., "The New Curriculum in Electrical Engineering at Lehigh University": *J. E. E*, Vol. 32, No. 5, January, 1942, page 434.

[2] Guillemin, E. A., "The Coordination of the Work of the Physics, Mathematics, and Electrical Engineering Staffs in the Formulation of Communications and Electronics Curricula, Including Ultrahigh-Frequency Techniques": *J. E. E.*, Vol. 35, No. 7, March, 1945, page 401.

trical engineering student starts to specialize in his chosen field and in the mathematics useful to him either in direct application or as training in analytical thinking.

It is my present purpose to discuss typical courses of a correlative type which may be found in the revised electrical engineering curriculum at Cincinnati where broad fundamental background is a prime objective. It should be mentioned that the shorter terms and more frequent intermissions in the form of work-sections make it possible to give the cooperative student a more intensive curricular schedule than would be feasible for a student attending classes eight or nine consecutive months during the year. Thus the five-year cooperative electrical engineering program at Cincinnati contains a total of more than 4100 contact hours, and is believed to be greater than that of any standard four year curriculum.

The sophomore course called Graphical Methods to which Dr. Justice referred carries over into the third term. It is extremely useful in helping the student bridge the gap between the more precise analytical methods he has learned through the Calculus and more practical methods of effective compromise which are of necessity found in modern engineering.

Another sophomore course of value is a lecture course entitled Applied Kinematics, accompanied by a Kinematics Design Laboratory. The lectures start with vector calculus and deal with the analysis of simple mechanisms in plane motion. Vector methods are used exclusively in anticipation of their need in field theory. The laboratory course includes the development of simple speed-time schedules for electric railway transportation, and the design and drawing of simple electrical devices such as circuit breakers, pantograph switches, and motion picture mechanisms.

For three terms in the pre-junior year the student of electrical engineering gets his most important applied mathematics course. It is called Mathematical Methods in Electrical Analysis and is intended to accomplish two broad objectives: first, the ability to formulate and interpret physical situations in mathematical terms by the use of fundamental principles; and second, a working knowledge of the technical tools of modern mathematical methods. This philosophy of teaching both the qualitative and quantitative aspects of mathematics is substantially that discussed by Professors Bryan,[3] Miller,[4] Grinter[5] and Synge[6] in previous issues of the JOURNAL OF ENGINEERING EDUCATION.

The actual content of this course is comprised of the following subject matter:

1. Review of basic principles of mechanics and their electrical analogies, dual systems, lumped parameters and need for ordinary differential equations.
2. Ordinary linear differential equations with constant coefficients, graphical and numerical methods,

[3] Bryan, Noah R., "Improving the Mathematics Preparation for Specializing in Technical and Scientific Fields": *J. E. E.*, Vol. 34, No. 10, June, 1944, page 664.

[4] Miller, Frederic H., "Mathematics Beyond Calculus for Engineering Students": *J. E. E.*, Vol. 37, No. 4, December, 1946, page 330.

[5] Grinter, L. E., "Teaching Mathematics to Engineers": *J. E. E.*, Vol. 37, No. 7, March, 1947, page 536.

[6] Synge, J. L., "Undergraduate Preparation for Graduate Study . . . Through Applied Mathematics": *J. E. E.*, Vol. 37, No. 7, March, 1947, page 531.

vector representation of damped sinusoids, application to single and double energy transients, amplitude modulation and beat phenomena.

3. Distributed parameters and need for partial differential equations, linear homogenous equation for the ideal line, traveling wave solution and boundary conditions for D.C. line, separation of variables and standing wave solution for A.C. line.
4. Synthesis of complex wave forms, Fourier series analysis, principle of superposition, applications to circuits with harmonic distortion, harmonic analysis. Exponential form of Fourier Series, the Fourier Integral and frequency spectra, application to ideal transmission systems.
5. Series solution of differential equations, Bessel and Gamma functions, application to eddy currents, skin effect and freqency modulation.
6. Heaviside operational calculus and Laplace transform analysis, comparison with previous methods of transient and steady state analysis of circuits and lines.

The amount of time devoted to individual topics is roughly proportional to their subsequent need and importance. Two texts have been used with notable success in conjunction with this course: *Advanced Mathematics for Engineers* by Reddick and Miller, and *Mathematical and Physical Principles of Engineering Analysis* by Johnson.

A course in Field Theory runs collaterally during the third term and stresses the vector analysis of fields, Maxwell's equations and Poynting's theorem. Also, a Transients Laboratory course is a valuable adjunct in correlating the analytical methods of transient analysis with laboratory results. Experimental methods in studying recurring and non-recurring transients in linear circuits are carried out giving the student incidental experience with oscillographic and photographic techniques.

By this time the student has an adequate mathematical preparation for the electrical courses of the junior and senior years. Junior courses requiring this preparation to a greater degree than others include Transmission Networks, Networks Laboratory, Transmission Line Theory, Electric Power Transmission, and Unbalanced Polyphase Systems

At the senior or early graduate level it is difficult to cite certain courses as typifying correlation more than others since the majority of electives are essentially mathematical in their approach, whatever the student's option This would include Servomechanisms, Electron Inertia Effect and Ultra High Frequency Techniques, Radiation and Propagation, Engineering Acoustics, Matrix Analysis and Tensors. In the majority of these courses the mathematics and electrical engineering are inseparable, making it impossible to distinguish where the one begins and the other ends.

Undoubtedly some will say that this is carrying things too far; that it is unnecessary to subject a student to so much "high-powered" mathematics as an undergraduate. Industry itself is divided on the subject. In the May, 1943 issue of the JOURNAL OF ENGINEERING EDUCATION, a paper by Mr. Stevenson [7] of the General Electric Co.

[7] Stevenson, A. R., Jr., "What Mathematical College Training Industry Expects from Young Engineers": *J. E. E.*, Vol. 33, No. 9, May, 1943, page 670.

entitled "What Mathematical College Training Industry Expects from Young Engineers" said in part: "It will be necessary to omit from the undergraduate engineering course specialized subjects such as Heaviside's method of solving differential equations, vector analysis, tensor analysis, special courses in circuit analysis etc., all of which are valuable but should be postponed to post-graduate years either in college or in industry for those with special aptitudes along these lines."

With this I most heartily disagree! One need only to sample random copies of such professional journals as *Electrical Engineering* and *I.R.E. Proceedings* to realize what mathematical equipment the serious technical reader is expected to have. It becomes obvious too that the situation involves more than just "tricks of the trade" to be learned on a co-op job or after graduation. Perhaps it is because of this need that so many graduates of former years feel like mathematical illiterates and are expressing their desire for courses in advanced mathematical methods from our evening colleges and industrial training programs.

It is evident that effective applied mathematics in electrical engineering courses can be taught best by faculty members having training in both fields —a sort of "mathematical engineer." At Cincinnati this is accomplished in two ways. The Department of Mathematics is large and its personnel has been selected from all fields of engineering and science, whereas the Electrical Engineering Department has several members who have special qualifications in graduate mathematics. In addition, both departments have representation on the teaching staff of the Graduate Department of Applied Science, thereby securing a fuller perspective and appreciation of the need for both inter- and intra-departmental correlation.

While there may be a diversity of opinion concerning the details of curricula at particular schools, there are underlying principles of correlation independent of institutions. In addition to the natural coordination between classroom and laboratory courses in electrical engineering, there is an evergrowing need for judicious correlation with mathematics. Such correlation pays great dividends in the amount of subject matter which can be covered adequately and effectively, a situation which the present and future demand.

Engineering Mathematics*

By V. G SMITH

Professor of Electrical Engineering, University of Toronto

In speaking of "Engineering Mathematics" to a group composed largely of university teachers, one naturally tends to restrict the subject somewhat to the teaching of mathematics to engineering students. Most of my remarks will be along that line but I first wish to make a few general observations.

Thinking of engineering mathematics, one might easily ask why the mathematics of engineering should be in any way special. The answer seems to be largely in the point of view. For engineers, mathematics is a tool used to find the answer to some question or questions and not an end in itself. They have at their disposal other means of finding answers to questions; model construction, experimental measurement, and graphics, any and all of which are combined with each other and with mathematics. One of the arts of engineering is in deciding just what combination of methods will yield the required answers with the least total effort.

Another respect in which engineering mathematics differs is this. Applied mathematicians frequently simplify a particular problem and find a general solution which covers a large number of cases, none of which quite agrees with the original problem. Such solutions are often of great utility and usually can be made the basis of more exact solutions by improved approximations. The engineer, however, must usually, for economic reasons, secure a sufficiently exact numerical solution to a particular problem, however inelegant his methods. I have, for example, several times spent up to three weeks at six and three-quarter hours a day computing what the power system of the H.E.P.C. of Ontario would do in one second. Such problems account for the building of expensive network analysers, differential analysers, and elaborate computing machines.

Finally, in engineering mathematics the special cases and exceptions (which are often the most difficult part of formal mathematics) seldom arise. Thus an engineer is quite safe in taking Fourier's Theorem to be "*Any* periodic, single-valued function may be expanded . . . ," and I have never seen a practical case in which the remainder of a Taylor's series did not vanish when the series itself converged. This does not mean that the engineer should be left in ignorance of the exceptions; they should be pointed out, preferably with examples, but with very little time spent on them.

While at the undergraduate level one can notice a great difference in the required mathematics of the various branches of engineering, this difference disappears at the graduate level. Modern electrical engineering seems to re-

* Reprinted from the Proceedings of the *Canadian Mathematical Congress*, Montreal, June 18–23, 1946.

quire a more extensive knowledge of mathematics than the other branches but they are rapidly catching up. A good communication specialist should have a sound working knowledge of circular, exponential, hyperbolic, and Bessel functions for real and complex variables, together with the differential equation and function theory background. Fourier analysis is essential and Laplace transforms or operational methods are desirable. Vector analysis is pre-requisite to electromagnetic theory and determinants and matrices are a necessary background.

A word of caution might be inserted here. We have been talking of a rather small class of engineers; the technical specialists, the research type. Often this is the only type in which mathematicians are interested but there must be many engineers doing work of a lower mathematical standard, or even none at all, for each research engineer.

Engineering Physics at Toronto. Dr. Pall has asked me to say something about the Engineering Physics Course at Toronto. This course was organized in 1935 and commenced that autumn with *seven* students; last September, *forty-four* students entered the course. Only students with first class honours in Grade XIII Mathematics and a high general average are admitted, consequently the average ability of the group is very high. There are, however, students just as able in the ordinary engineering courses, a fact which is sometimes overlooked. The first two years of the Engineering Physics Course are common but in the third year there is some division depending upon the fourth year option chosen.

The engineering physics students take most of their mathematics and physics with the Arts mathematics and physics students and so absorb the atmosphere and enthusiasm of the arts faculty for those subjects. On the other hand they spend most of their time with the engineering students and get the viewpoint of engineering. The net result is that they are highly critical of many features of both sides of the road; to the ultimate benefit, I am sure, of both. Certain it is that each engineering physics student has to do a lot of weighing, comparing, and judging that ordinary students of either arts or engineering never do. That these students are having an effect upon the ordinary engineering students is shown by student suggestions for course improvements and that they have an effect upon physics students is shown when ten arts students cross the road to take engineering lectures.

There is no point in trying here to compare in detail the Engineering Physics Course with the other engineering courses but some remarks may be of interest.

In the third and fourth year, subjects can be given to the Engineering Physics students which are too mathematical for the other courses, such as electromagnetic theory to the Electricity and Communication Option. On the other hand that option misses, owing to lack of time, hydraulics, heat engines, business machine design, engineering law, and the lectures on alternating current machinery, but not the laboratory. Note that it is the mechanical subjects which have suffered. Only a close study of the calendar will disclose all the differences.

Personally, I regard the Engineering Physics Course as the best preparation we offer to men who have the necessary qualifications and who wish to become technically expert with a view to research work of some kind, though I

realize quite well that some of my colleagues would disagree with me. The one universal criticism and real fault with the course is that it is too crowded and that the student does not have time to think I believe that this is true, but just try to get agreement, even among the students, on the proper subjects to remove!

Undergraduate Engineering Mathematics. Before speaking on the subject of undergraduate engineering mathematics, I should state that I have never taught first or second year mathematics except incidentally in a course on electrical circuits and measurements. I am therefore speaking as one who is dealing with the product of the usual undergraduate mathematics course.

It will be admitted by all concerned, I think, that the percentage of failures in the first year calculus and analytical geometry and in the second year calculus at Toronto is very high Probably this is the same in other institutions. But we find the same thing occurring when dynamics and statics are taught from an analytical viewpoint and problems requiring real thinking are set. What then is the answer?

I never think of this question without coming to the conclusion that the range of student ability is too great for a single class and that there should be some form of separation into at least two groups, call them honours and pass or what you will. Some students complain that not enough new material is presented in the second year calculus and yet the failures are many. Some professors of mathematics and physics seem to feel that the elimination of these poor mathematical students from engineering is all to the good. In many cases this is true, but we must never forget that engineering is a broad field and many mathematically mediocre students of the past are doing excellent work in executive, manufacturing, and sales positions By the way, it *does* require a trained engineer to sell some engineering products intelligently.

Apart from the range of ability I feel that one of the chief difficulties in teaching undergraduate engineering mathematics is the general lack of interest and enthusiasm on the part of engineering students for the subject Whether this fault lies with the students, the engineering staff, or the mathematics staff I cannot undertake to say, for the engineering staff arouses considerable student interest in other subjects and the mathematics staff certainly arouses interest in mathematics among the engineering physics and arts students Probably the dice are loaded that way by the student selection of their courses in the first place But are there not ways of arousing more interest in mathematics among engineering students?

Why not introduce each new idea in an easily visualized physical problem? For example, differentiation as the problem of the policeman measuring the speed of an automobile going down the street or the problem of the surveyor measuring the slope of a hill, integration as the problem of finding the capacity of a wine cask. Personally I have always had extreme difficulty in learning any mathematics just because I wanted to learn it, but have usually found it very easy when it was incidental to some physical problem Perhaps others are the same.

The fundamental concepts of the elementary calculus are really quite easy to grasp but traditionally the subject is regarded as difficult, as a hurdle that must be jumped and then for-

gotten. In the past both the staff and practising graduates of engineering have not been guiltless of fostering this unfortunate tradition. Such ideas are now rapidly disappearing. To those teaching the elementary calculus may I suggest that they treat it from an application point of view *at first*, tie it to physical problems, and make sure their assumptions correspond closely to nature, and divorce it as much as possible from geometry, which is itself difficult to many engineering minds. The separation of the calculus from physical problems at a later stage should be more or less natural. In this way it is believed that a greater interest would be aroused. I really learned to appreciate what the calculus was all about in hydrostatics, working out centres of pressure, centres of buoyancy, etc. The integrations were simple enough and the overall picture became clear.

In teaching elementary differential equations always introduce three or four problems which depend upon its solution *before* finding the solution. In more advanced work the problems can be taken simply as examples. Thus in Bessel functions we may consider the Fourier analysis of an elliptical wave, the side bands of a frequency modulated signal, and any wave problem having cylindrical symmetry as typical examples.

I realize, of course, that the question of physical problems is a delicate one. The mathematics teacher is often not too familiar with them, nor indeed too interested in them, and he is always a bit afraid of stepping on someone's toes should he choose dynamics problems or electric circuit problems. Surely here is a place for cooperation between the staffs.

How about the early incidental *use* of complex numbers and elementary complex functions in a purely formal manner, almost as though no special investigation were necessary? This subject always seems to arouse student interest and few special rules are involved; and perhaps the mathematicians will deign to use the hated j (which was introduced by a mathematician), at least until the engineering profession has learned to use i. Hyperbolic functions should be used freely. Define them and derive their properties as you need them. Most students have short tables of these functions and are inquisitive about them. Why should integrals which are most naturally expressed in hyperbolic functions or their inverse, be always expressed as combinations of exponentials or complicated logarithms?

Many students fail in calculus in part at least because of lack of facility in algebra. A brief review of the laws of algebra does, I know, arouse interest, especially as emphasis can be laid upon the philosophy of the steps from arithmetic algebra to symbolic algebra and from positive integral indices to fractional and negative indices, including the binomial theorem, which most students have never taken generally. Later the exponential and logarithmic functions can be derived without too much attention to rigour and the calculation of some logarithms set as an exercise. These things can be done in an incidental manner and need not absorb too much time.

I firmly believe that every mathematician should do some calculating for the good of his soul. Often a clearer understanding of a problem is obtained in this way than can be obtained in any other. Many correct formulas are unsuited to computation and much ingenuity is often needed to overcome

this. One of the first shocks that many mathematicians experience is to find that convergent series are usually quite useless for practical computations. Engineering students in particular require numerical examples. If the problem has an algebraic solution, particular numerical cases should be worked out or set as problems.

The arousing and maintaining of interest in mathematics is one of the chief problems in teaching engineering students. Perhaps some of the suggestions made here will help.

Lastly there is one ridiculous obstacle to mathematics for many engineering students; the Greek alphabet. The late Professor T. R. Rosebrugh introduced the so-called general circuit constants into electrical engineering and called them α, β, γ, δ. Some years ago I suggested to him that he change to a, b, c, d, as had become common usage elsewhere, on the grounds that whereas the average student knew no Greek, he was supposed to know his a, b, c's. The scheme seemed to work. I suggest that each engineering student be required to memorize the Greek alphabet and learn how to write it himself. Ridiculous as it is, I think it would help.

Teaching Engineering Gyroscopics

By WILLIAM R WEEMS

Assistant Professor of Aeronautical Engineering, Massachusetts Institute of Technology

Although the gyroscope is familiar to everyone as a toy and to some as a mathematical exercise, its practical exploitation has been in progress only since early in the 20th century. Nevertheless, it has already achieved general acceptance as being uniquely qualified to perform many essential functions. At the same time, there seems to be a widespread feeling, even among engineers, that there is something mysterious about a gyroscope. Many do not make any attempt to understand it and teachers are handicapped by paucity of text material and the general mental block that seems to spring up whenever three-dimensional problems are encountered.

In view of the ever-increasing importance of gyroscopes, it is likely that more and more teachers will be including a treatment of gyroscope theory in their courses. Therefore, it may be helpful to consider briefly the approach that has been evolved at M.I.T., where gyroscopic theory has been taught and utilized in research and development projects for a number of years. This approach is embodied in the unique presentation of gyroscopic theory which has been developed by Dr. C. S. Draper, Director of the Instrumentation Laboratory at M.I.T. It effectively removes the aura of mystery from the gyroscope and transforms it into an easily understood and precise element of instrumentation.

This presentation is characterized by an initial analysis of the most general gyroscope situation of engineering interest, from which all subsequent applications of the gyroscope can be explained by specialization. Thus the student is helped to understand each gyro device studied and to relate each to the others, keeping in mind always the essential physical laws common to all gyroscopes. This is in contrast to the lack of perspective, if not actual confusion, resulting from the more usual presentation of the subject, wherein each application is analyzed as an isolated problem.

The obvious advantages of the generalized presentation might be seriously diminished by its complexity if it were not for the use of methods designed or chosen to assist the mind in handling the *three-dimensional* concepts involved. The word *three-dimensional* should be stressed because it appears that all of the common difficulties encountered in teaching the subject have their roots in the fact that it deals with three dimensions simultaneously, while the students are generally unfamiliar with reasoning in more than two dimensions. The methods used assist the mind by:

(1) Simplifying the graphic representation of the problem.

(2) Releasing the mind from the limitations of having to think in

terms of components along coordinate axes, so that it can concentrate on the physical aspects of the problem.

(3) Incorporating a system of symbols which implies the essential qualities of the physical quantities involved, including similarities and differences among them.

Item (1), simplification of the graphic presentation, is accomplished first of all through the representation of essential quantities as vectors, using the usual right hand sense rule Thus, a torque is represented by a vector along its axis and is referred to as a torque "about such and such an axis" rather than a torque "in such and such a plane." Only those who have tried to draw free hand sketches of gimbal systems and gyro wheels on short notice can appreciate fully the simplification that can be effected by reducing everything with vector properties to actual vectors in the graphical representation. A second type of simplification is effected in the mathematical analysis by the free use of Euler's angles to express the relationships among the various frames of reference that are required in analyzing the gyroscope.

Item (2) is accomplished by utilizing the powerful notation of vector analy-

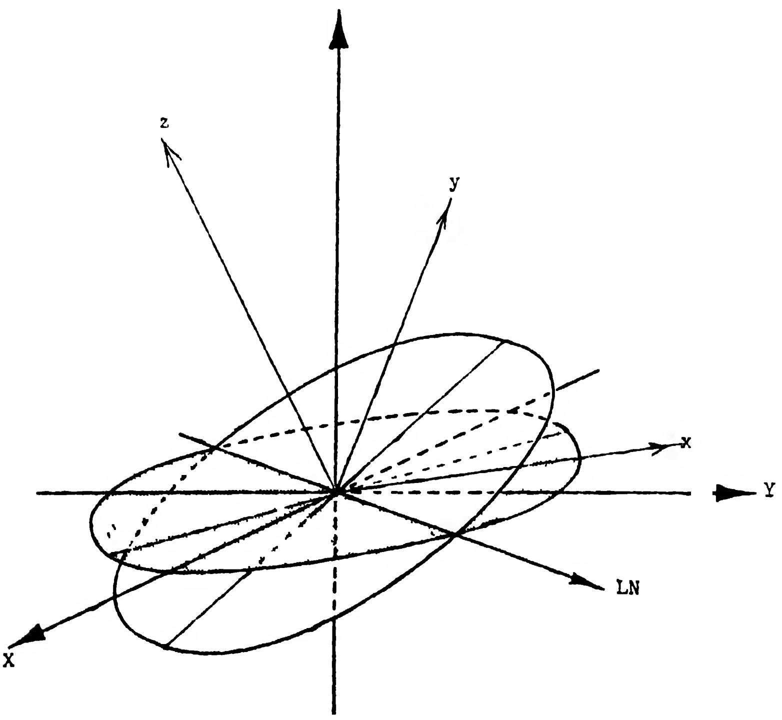


Fig. 1

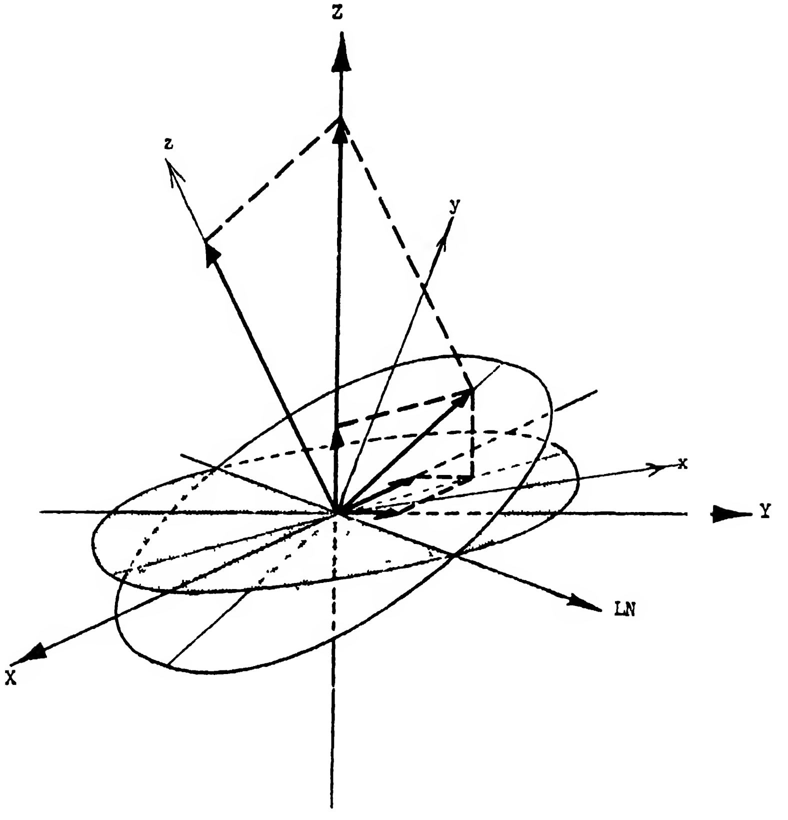


FIG. 2

sis. Although this is unfamiliar to many engineering students, a little practice in the simpler aspects of it normally serves to win them over to its great utility in doing the bookkeeping of components and trigonometric resolutions automatically. Actually, the only vector operations that are required are addition and subtraction, scalar and vector products, and differentiation of a vector; the more difficult operations used in analyzing field problems are not needed.

Item (3) refers to a sytem of symbols involving multiple subscripts. It is beyond the scope of this paper to go into the details of the system, but the basic idea of multiple subscripts is commonly known. The involved dynamical and geometrical situations connected with gyroscopic analysis merely call for a certain degree of codification of the system in seeking the maximum utility.

It may seem to one not familiar with the situation that the type of presentation outlined would require the devotion of an undue proportion of the time to familiarizing the student with fundamental concepts implicit in the notation and symbols used. It is true that a considerable proportion of the time has to be spent on these fundamentals. But it has been found that,

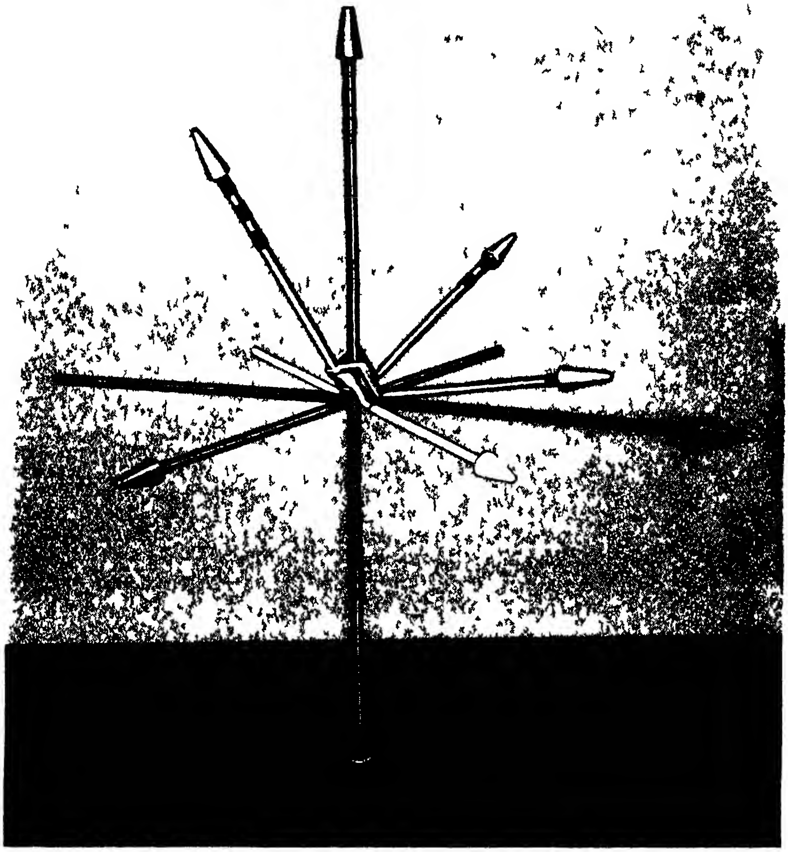


FIG 3

instead of hindering, this actually helps the student in obtaining a clearer and firmer understanding of the gyroscope within the allotted time Once these fundamentals have been mastered, for example, the key to almost all engineering analyses involving the gyroscope is the simple and concise equation

$$\bar{M}_{(app)} = \bar{W}_{IFI} \times \bar{H}$$

In this expression, $\bar{M}_{(app)}$ is the applied torque, $\bar{W}_{IFI}$ is the angular velocity of the inner gimbal with respect to inertial space and $\bar{H}$ is the angular momentum of the gyroscope (all vector quantities).

If it is granted, then, that the analysis of an inherently three-dimensional problem properly involves the use of three-dimensional tools, even though they may be unfamiliar at first, there still remains the pedagogical problem of how to get these unfamiliar ideas across with the minimum of confusion The principal difficulty does not lie in the notation of vector analysis itself; there are numerous good references on this subject, and a rather shallow penetration of them is adequate for this purpose The real difficulty lies in visualizing and organizing the three-dimen-

sional picture. This applies particularly to the familiarization with Euler's angles and the derivation of the various sets of transformation equations involved in referring vector quantities expressed in terms of different sets of coordinates related by Euler's angles. Most teachers, and certainly most students taking notes, are not good freehand artists. Our blackboards and note paper are definitely two-dimensional. Indeed it is quite possible, especially at the beginning of a course, for the teacher to draw what he considers a clear sketch of a three-dimensional situation and then have to spend half of the hour dispelling the optical illusions of various students.

A satisfactory answer has been found in the use of a few three-dimensional models, fortified by mimeographed sketch sheets supplied to the student. These sketch sheets furnish the student the same basic construction lines the teacher habitually uses in sketching situations on the blackboard. One of the blank sketch sheets is illustrated in Fig. 1. Fig. 2 depicts the same sheet containing a sketch used in a classroom derivation. To assist instructors in preparing sketches for classroom presentations which will be neat and easily

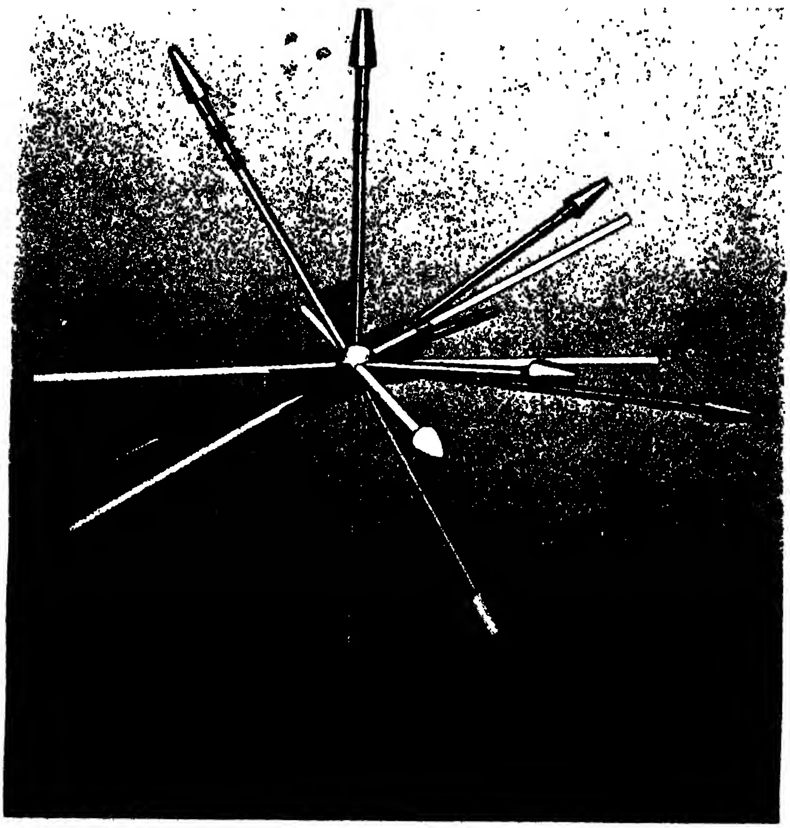


FIG. 4

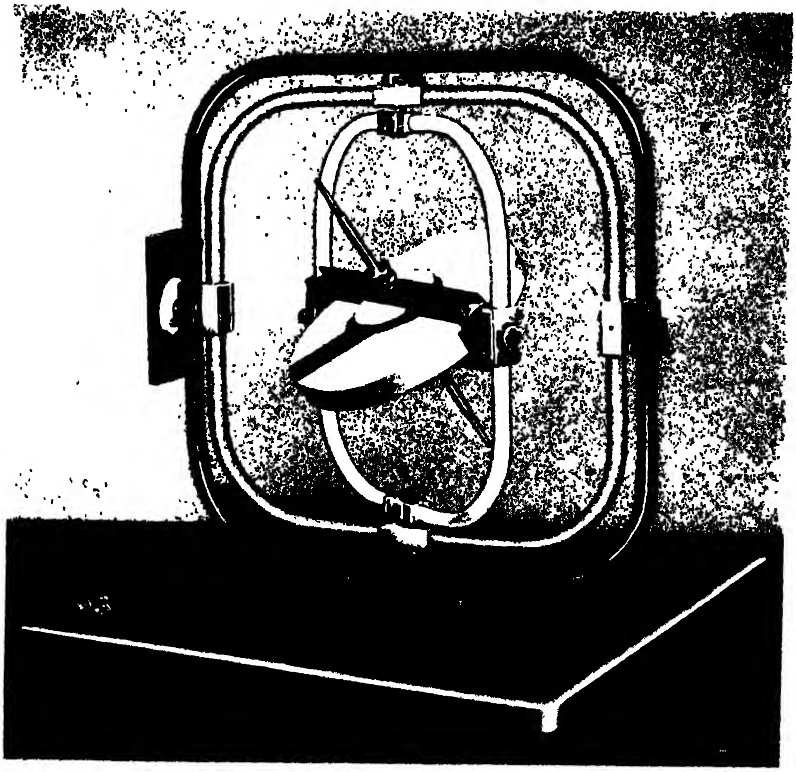


Fig. 5

copied on the students' sketch sheets, there has even been prepared a special light blackboard panel about three feet square, with permanent sketch guide lines on it. These guide lines are an enlargement of those on the students' sketch sheets and are drawn on the black surface with india ink, so that they are quite clear to one close up but not noticeable to one a few feet away.

In illustrating lectures and in actually working out certain basic three-dimensional resolutions, the space models of Figs. 3 and 4 are used. These models show a set of reference axes (X, Y, Z of Figs. 1 and 2), with another set of axes (x, y, z) arbitrarily oriented with respect to them. The angles used to relate the two sets of axes are Euler's angles. Fig. 3 depicts a model in which the various lines are represented by metal rods which actually move in appropriate sets about the correct axes to duplicate, within the limits of mechanical interference, the angular displacements represented by the three Euler's angles. In Fig. 4, all rods are fixed, allowing the attachment of transparent panes to assist the eye in organizing the picture. These panes furnish a convenient means of labeling the angles, and the fixed rods are useful for illustrating trigonometric resolutions by means of colored adhesive tapes stretched from point to point. In both models vivid and contrasting colors are utilized to aid the eye in seeing the axes in sets.

The most useful model of all—one which is used during all phases of the subject—is the one illustrated in Fig. 5. This is a working model gyroscope which operates on ordinary 60 cycle current and which is designed specifically for the teaching job. It makes use of vivid colors to differentiate the various frames and is fitted with a number of attachments which provide means for applying torques to the gyro element, means for measuring angular displacements, and means for altering the non-rotating inertias by definite amounts. Provision is made, also, for locking any two consecutive frames together as desired and for orienting the gimbal system in various ways with respect to the vertical. The rotor is a heavy wheel that rotates slowly enough that a reference stripe on it can be seen by the students at all times. This slow speed is used primarily to enable an observer to sense the direction and speed of rotation, but has a secondary advantage in that it causes the nutational frequencies to be low enough for oscillations to be timed by use of visual observations and a stopwatch in covering that aspect of gyroscopics. The demonstration gyroscope is used, not only to illustrate lectures, but also in the laboratory for experiments which emphasize the *quantitative* aspects of gyroscope theory. For this purpose, the gyro model is used in conjunction with a motor-driven turntable for furnishing forced precessions. It is usual, and of course highly desirable, for the students taking the theoretical work on gyroscopics to take a concurrent laboratory course which contains a number of experiments designed to buttress the theoretical coverage.

Another short article, describing these teaching aids in more detail, is contemplated for the near future. Questions, criticisms and suggestions are invited, as they will be helpful in its preparation.

Comments on Mechanics Analysis

By R M COOK

Assistant Professor of Civil Engineering, Northwestern University

Professor Wyly's notes on the philosophy of stress analysis in the JOURNAL OF ENGINEERING EDUCATION, Vol 37, April, 1947, needs some comment. While no one can disagree with his emphasis on the importance of signs in the analysis of indeterminate problems such as the bent illustrated in Fig. 2 of his article the writer wonders if the emphasis placed on the importance of signs in the analysis of the simple problems is justified

Signs in the writer's viewpoint are a necessary evil of much of the theoretical work of the engineer Signs are given to moments, forces and rotations in those cases when there is doubt as to the direction of the moment, force or rotation.

In the case of the simple beam where the direction and magnitude of the reactions are practically obvious, signs in the writer's experience are "confusers" and "mistake makers." Part of this viewpoint from the writer's standpoint is due to his concept of the equilibrium relations which he wishes to emphasize here.

Primarily the equations $\Sigma M = 0$, $\Sigma V = 0$, and $\Sigma H = 0$ are "balancing equations." In other words they say (1) that the sum of the moment of forces about one axis in one direction must be balanced by an equal sum of moment of forces in the opposite direction about the same axis, (2) that the sum of forces pushing a body *up* must be equal and balance the sum of the forces pushing the body *down*, (3) that the sum of the forces pushing a body to the *left* must be equal and balance the sum of the forces pushing the body to the *right*

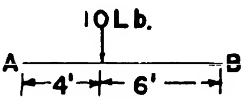


FIG 1.

The writer has felt for many years that our textbooks lose this visual concept of "balance" that is so important in the analysis of problems in statics by cluttering up our equations with a large group of numbers equal to 0. We would do better to write our equations as balancing equations placing our equal sign in the middle.

For illustration let us look at the simple beam of Professor Wyly's article (Fig. 1).

If the support at A were removed the beam would collapse but the collapsing would be in the form of rotation about B (Fig. 2). Therefore it seems very logical to "balance" moments of forces about an axis through B to determine the force needed at A to place the beam in equilibrium. The equation $\Sigma M_B = 0$ would then be written as a balancing equation $10 \times 6 = V_A \times 10$, solving then $V_A = 6$ lbs. and the direction of V_A is such as to prevent rotation of the beam about B.

"Balancing" vertical forces then, 10 lbs. acting down must be balanced by 10 lbs. acting up, then $10 = 6 + V_B$ or $V_B = 4$ lbs. acting up as shown in Fig. 3.

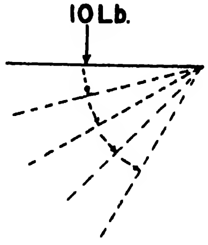


FIG. 2

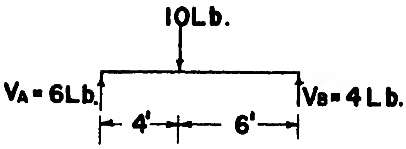


FIG. 3

The statement in most mechanics books that counter-clockwise moment is to be considered positive, the writer believes is confusing to students, for in their strength of materials course and structural courses they find other conditions govern the sign of moments of forces. The writer, therefore, believes that this statement could be omitted from mechanics books and emphasis placed on conditions of balance rather than signs.

To carry this concept of balance a little further models of some simple structures have been found helpful. If the student can properly visualize the action of a structure upon the removal of a constituent member the proper axis about which to balance moment of forces is practically obvious as that axis about which the structure would rotate in collapsing.

For example, Fig. 4 is a simple Pratt through bridge truss with a load at joint D.

If we wish to know the force in member CD just remove member CD and note the collapse of the structure. In collapsing the structure would sometime assume the shape in Fig. 5. It seems obvious that member CD is a tensile member and that the normal axis through joint A is the proper axis about which moment of forces should be balanced to determine the force in CD.

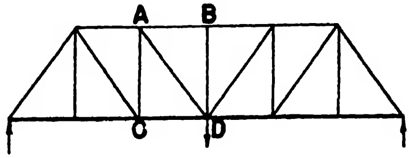


FIG. 4

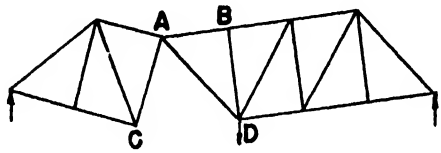


FIG. 5

The writer has developed a model for use with students in mechanics to illustrate this point and other points. The model is a small Pratt truss with flexible members any or all of which can be blocked out with solid members.

Fig. 6 is a photograph of the model with a load at joint G showing the sag of the whole structure, compression in the top chord, tension in the lower chord, and the tension and compression coming in the diagonals and verticals. The model exaggerates the deformation and is used purely for illustration purposes.

Fig. 7 is a photograph of the model with every member blocked out with solid members, except member DF. As the structure is collapsing by rotation about an axis through joint G,

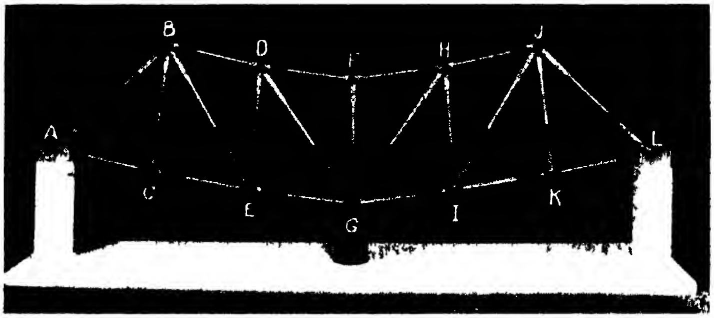


Fig 6

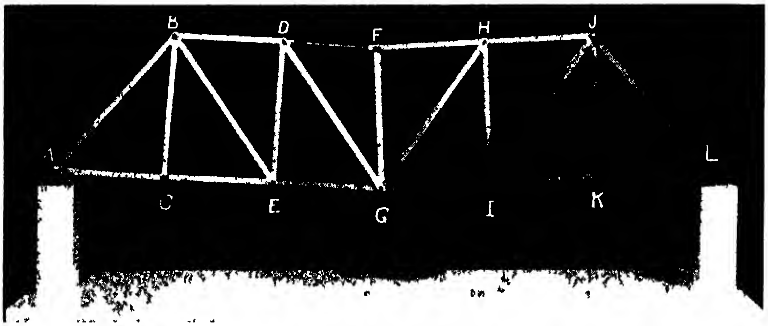


Fig 7

it would be logical to balance the moments of forces about this axis to determine the force in DF

While the principles presented in this article are not particularly new the writer believes they are extremely helpful to the beginning student in mechanics and should be emphasized

While no one can argue the importance of the proper handling of signs in indeterminate stress analysis using the Moment Area or Slope Deflection relations, the writer believes that training in visualization and application of the principle of balance thereto is of prime importance in the field of mechanics

Canons of Ethics for Engineers

The Canons of Ethics for Engineers were prepared by the Committee on Principles of Engineering Ethics of the Engineers' Council for Professional Development. Members of this committee, representing all of the constituent societies, collaborated in the preparation of the final draft. The Canons have been approved by the Council of the Engineers' Council for Professional Development and will be officially adopted when approved by the constituent societies. They were approved by the General Council of the American Society for Engineering Education at its meeting in Washington on November 11, 1947.

Foreword

Honesty, justice and courtesy form a moral philosophy which, associated with mutual interest between men constitutes the foundation of ethics. The engineer should recognize such a standard, not in passive observance, but as a set of dynamic principles guiding his conduct and way of life. It is his duty to practice his profession according to these Canons of Ethics.

As the keystone of professional conduct is integrity, the engineer will discharge his duties with fidelity to the public, his employers and clients, and with fairness and impartiality to all. It is his duty to interest himself in public welfare, and to be ready to apply his special knowledge for the benefit of mankind. He should uphold the honor and dignity of his profession and also avoid association with any enterprise of questionable character. In his dealings with fellow engineers he should be fair and tolerant.

Professional Life

Sec. 1. The engineer will cooperate in extending the effectiveness of the engineering profession by interchanging information and experience with other engineers and students and by contributing to the work of engineering societies, schools and the scientific and engineering press.

Sec. 2. He will not advertise his work or merit in a self-laudatory manner, and he will avoid all conduct or practice likely to discredit or do injury to the dignity and honor of his profession.

Relations with the Public

Sec. 3. The engineer will endeavor to extend public knowledge of engineering, and will discourage the spreading of untrue, unfair, and exaggerated statements regarding engineering.

Sec. 4. He will have due regard for the safety of life and health of the public and employees who may be affected by the work for which he is responsible.

Sec. 5. He will express an opinion only when it is founded on adequate knowledge and honest conviction while he is serving as a witness before a court, commission or other tribunal.

Sec. 6. He will not issue ex parte statements, criticisms or arguments on matters connected with public policy which are inspired or paid for by private interests, unless he indicates on

whose behalf he is making the statement.

Sec. 7. He will refrain from expressing publicly an opinion on an engineering subject unless he is informed as to the facts relating thereto.

Relations with Clients and Employers

Sec. 8 The engineer will act in professional matters for each client or employer as a faithful agent or trustee

Sec. 9. He will act with fairness and justice between his client or employer and the contractor when dealing with contracts.

Sec. 10. He will make his status clear to his client or employer before undertaking an engagement if he may be called upon to decide on the use of inventions, apparatus, or any other thing in which he may have a financial interest.

Sec. 11. He will guard against conditions that are dangerous or threatening to life, limb or property on work for which he is responsible, or, if he is not responsible, will promptly call such conditions to the attention of those who are responsible.

Sec. 12. He will present clearly the consequences to be expected from deviations proposed if his engineering judgment is overruled by non-technical authority in cases where he is responsible for the technical adequacy of engineering work.

Sec. 13. He will engage, or advise his client or employer to engage, and he will cooperate with, other experts and specialists whenever the client's or employer's interests are best served by such service.

Sec. 14. He will disclose no information concerning the business affairs or technical processes of clients or employers without their consent.

Sec. 15. He will not accept compensation, financial or otherwise, from more than one interested party for the same service, or for services pertaining to the same work, without the consent of all interested parties.

Sec. 16. He will not accept commissions or allowances, directly or indirectly, from contractors or other parties dealing with his client or employer in connection with work for which he is responsible.

Sec. 17. He will not be financially interested in the bids as or of a contractor on competitive work for which he is employed as an engineer unless he has the consent of his client or employer.

Sec. 18. He will promptly disclose to his client or employer any interest in a business which may compete with or affect the business of his client or employer. He will not allow an interest in any business to affect his decision regarding engineering work for which he is employed, or which he may be called upon to perform

Relations with Engineers

Sec. 19. The engineer will endeavor to protect the engineering profession collectively and individually from misrepresentation and misunderstanding.

Sec. 20. He will take care that credit for engineering work is given to those to whom credit is properly due.

Sec. 21. He will uphold the principle of appropriate and adequate compensation for those engaged in engineering work, including those in subordinate capacities, as being in the public interest and maintaining the standards of the profession.

Sec. 22. He will endeavor to provide opportunity for the professional development and advancement of engineers in his employ.

Sec. 23. He will not directly or indirectly injure the professional reputation, prospects or practice of another engineer. However, if he considers that an engineer is guilty of unethical, illegal or unfair practice, he will present the information to the proper authority for action.

Sec. 24. He will exercise due restraint in criticizing another engineer's work in public, recognizing the fact that the engineering societies and the engineering press provide the proper forum for technical discussions and criticism.

Sec. 25. He will not try to supplant another engineer in a particular employment after becoming aware that definite steps have been taken toward the other's employment.

Sec. 26. He will not compete with another engineer on the basis of charges for work by underbidding, through reducing his normal fees after having been informed of the charges named by the other.

Sec. 27. He will not use the advantages of a salaried position to compete unfairly with another engineer.

Sec. 28. He will not become associated in responsibility for work with engineers who do not conform to ethical practices.

Sections and Branches

The Ninth Annual Meeting of the **North Mid-West Section** of the American Society for Engineering Education was held in Milwaukee, Wisconsin, on October 17 and 18, with Marquette University acting as hosts. Rev. P. A. Brooks, S.J., President of Marquette University, delivered the welcoming address at the banquet. Other speakers included B. G. Elliott on the "Faculty Viewpoint on Engineering College Problems," in which he gave a report of the findings of the University of Wisconsin College of Engineering Planning Committee, and A. von Wening, Vice President and Controller of the A. O. Smith Corporation, on the "Place of the Engineer in Industry."

The new officers for the North Mid-West Section include F. L. Partlo, Chairman; C. J. Posey, Vice Chairman; and S. R. Price, Secretary and Treasurer. The following board members were elected: D. W. Nelson, E. W. Johnson, R. O. Kallenberger, and H. J. Stoever.

Technical papers included the following:

Civil Engineering: "The Practical Aspects of Soil Mechanics," Albert T. Bleck; "Soil Mechanics as Taught at the University of Wisconsin," George W. Washa; "Undergraduate and Graduate Courses in Soil Engineering at Iowa State College," M. G. Spangler.

Electrical Engineering: "Some Aspects of Charged Particle Machines," Walther Richter; "Measuring and Photographing Periodic Transients," C. J. Schjonberg; "Popularizing the Study of Magnetic Fields," J. F. H. Douglas.

Engineering Drawing: Round Table Discussion of Topics Relevant to the Teaching of Engineering Drawing. 1. Psychological Impact of Drawing on the Student Body. 2. When do Fundamentals End and

Specialization Begin? 3. Theory and Practice of Engineering Drawing.

Mechanical Engineering. "Industrial Viewpoint on Shop Courses," Richard Falk; "Is the Second Law Indispenable in Engineering Thermodynamics," H. J. Stoever; "Application of Fluid Mechanics to Machinery," Walter Ferris; "Considerations in the Teaching of Advanced Machine Design," R. J Harker.

Theoretical and Applied Mechanics, and Mathematics: "The Closer Relations of the Mathematics and Mechanics Departments," George C Priester.

College Notes

The addition this October of nearly 150 new members brought the **University of Illinois College of Engineering** faculty to 468, the largest in its history. Appointments to the various professorial ranks include the following: as professor of physics, and dean of the graduate school of the University, Dr. Louis N. Ridenour; as visiting research professor in theoretical and applied mechanics, Dr. A M Freudenthal; as special research professor in ceramic engineering, Dr. W R. Morgan; as professor of physics, Dr. A. T. Nordsieck; as part-time lecturer and research consultant in clay mineralogy in the department of civil engineering, Dr. R. E Grim, photographer and principal geologist of the Illinois State Geological Survey; as associate professors in various categories—W. L. Hull, Everett Laitala and L. C. Pigage (mechanical engineering), Dr. H. L. Langhaar (theoretical and applied mechanics), and Dr. Henry Quastler (radiobiology, under physics); as assistant professors in various categories—G. F. Stockdale (ceramic engineering), L. G. Alexander (chemical engineering research), W. H. Munse, J. C. Dietz, E. R. Bretscher and E. J. Daily (civil engineering), Thomas A. Murrell (electrical engineering), Harry Czyzewski (metallurgical engineering), and R. D Hill and Dr R D. Rawcliffe (physics) The foregoing will engage in research, at least part-time

Additions to the teaching staff include: In aeronautical engineering, Associate Professor F R Stienbacher and Assistant Professor Jacque Houser; in electrical engineering, Assistant Professors D S Babb, J R. Barkson W. H Byers, P K. Hudson, J. P Neal, and H D. Webb; in mechanical engineering, Assistant Professor R. N McDonald; in theoretical and applied mechanics, Professor N O. Myklestad

Professor Harold L Walker, head of the department of mining and metallurgical engineering, returned in October from leave granted in April so that he might fulfill Governor Dwight Green's request that he serve as acting director of the State Department of Mines and Minerals.

Progress is being made in the construction of new buildings for the mechanical and electrical departments. The former staff hopes to have its structure available before February 1949. The electrical engineering building may be ready by September 1948. The mechanical building has a net floor

space of approximately 72,000 square feet, the electrical building of approximately 60,000.

The University of Illinois College of Engineering recently reported to the Engineering Experiment Station Record data on more than a dozen major projects, some new and some entering on significant new phases. These include betatron, cyclotron, highway drainage, and other investigations.

Cornell University announced the establishment of an endowed professorship of metallurgical engineering named for Francis Norwood Bard, owner of the Barco Manufacturing Company of Chicago. Mr. Bard made the formal presentation of a $250,000 fund to endow the professorship at a dinner in his honor.

The university also announced the appointment of Professor Peter E. Kyle as the first occupant of the chair, and redesignation of the School of Chemical Engineering as the School of Chemical and Metallurgical Engineering to place new emphasis on instruction and research in metallurgical engineering.

New Members

ANDERSON, HOWARD B., Instructor in Mathematics, Michigan College M. & T., Houghton, Mich. J. M. Harrington, W. A Longacre.

ANDERSON, W. CARLISLE, Assistant Professor of Engineering Drawing, Univ. of Okla., Norman, Okla. F S. Roop, R. V. James.

APPELGATE, JAMES M, Teaching Assistant, General Engineering, Univ. So. Calif., Los Angeles, Calif. K. C. Reynolds, L. R. Schruben.

BAKALER, ARNOLD, J., Instructor in Technical Drawing, Ill. Inst. Tech., Chicago, Ill. I. L. Hill, H. C. Spencer.

BELL, JOSEPH H., Instructor in Mechanical Engineering, Okla. A. & M. College, Stillwater, Okla. R. R. Irwin, E. R. Stapley.

BLACK, WINSTON E. Assistant Professor T. & A. M., Univ. of Illinois, Urbana, Ill. J. O. Smith, W. L. Collins.

BOCK, LESTER G. Lecturer in Mechanical Engineering, Univ. So. Calif., Los Angeles, Calif. E. K. Springer, T. T. Eyre.

BONE, HAROLD K., Assistant Professor of Engineering Drawing, Univ. of Okla., Norman, Okla. F. S. Roop, R. V. James.

BYERS, NORMAN R., Instructor in Machine Design, Kansas State College, Manhattan, Kansas. J. N. Wood, R. F. Morse.

CHEADLE, J. N., Instructor in Electrical Engineering, S. D. State College, Brookings, S. D. E. E. Johnson, W. H. Gamble.

CLARK, JOHN R., Assistant Professor of Electrical Engineering, Purdue Univ., Lafayette, Ind. L E Beck, D. T. Canfield.

DAASCH, HARRY L., Prof and Chairman, Dept. Mech. & Ind. Eng., Univ. of Kansas, Lawrence, Kansas. Re-admission.

DELEE, JOHN L., Assistant Professor of Engineering Drawing, Rensselaer Poly. Inst., Troy, N. Y. H. B Howe, H. O. Sharp.

DREHER, GEORGE K, Executive Director, Foundry Educational Foundation, Cleveland, Ohio. P. E Kyle, F. H. Rhodes.

FARRAR, CLYDE L., Professor of Electrical Engineering, Univ. of Okla., Norman, Okla. F. S. Roop, R. V. James.

FONER, DAVID N., Instructor in Civil Engineering, Swarthmore College, Swarthmore, Pa. S. B. Lilly, S. T. Carpenter.

FRASH, EDWIN S., Assistant Professor of Mechanical Engineering, Univ. of Florida, Gainesville, Fla. F. H. Pumphrey, Jos. Weil.

GERHARD, SHERMAN L., Assistant Professor of Physics, Newark College of Eng., Newark, N. J. P. O. Hoffmann, F. D. Carvin.

GRAY, CHARLES H., Head, English Dept., Rensselaer Poly. Inst., Troy, N. Y. F. Abbuhl, J. R. Gould.

HAWK, HAROLD W., Instructor in English, University of Colorado, Boulder, Colo. W. O. Birk, C. L. Eckel.

Hawkins, Harold V., Professor of Civil Engineering, Ill. Inst. Tech., Chicago, Ill. E. I. Fiesenheiser, P. C. Huntly.

Hecker, Charles H., Professor of Chemical Engineering, Clarkson College of Tech., Potsdam, N. Y. J. H. Daves, W. H. Allison.

Houghton, Richard W., Instructor in Electronics, Wentworth Institute, Boston, Mass. M. N. Anlin, C. W. Tudbury.

Kezios, Stothe P., Instructor in Mechanical Engineering, Ill. Inst. Tech., Chicago, Ill. R. A. Budenholzer, R. L. Rose.

Langford, Joseph W., Assistant Professor of Electrical Engineering, Univ. of Mass., Amherst, Mass. G. A Marston, J. D. Swenson.

Livingston, Noyes B., Assistant Professor of Engineering, Texas College of A. & I., Kingsville, Texas. F. W. Dotterwert, E. Koryes.

Lothers, John E., Professor of Architecture, Okla. A. & M. College, Stillwater, Okla. R. G. Saxton, R. L. Flanders.

Lucas, James H., Associate Professor of Civil Engineering, Georgia School of Tech., Atlanta, Ga. T. H. Evans, J. M. Smith.

Mason, James H., Lecturer in General Engineering, Univ. So. Calif., Los Angeles, Calif. D. M. Wilson, A. Hansen.

Maxey, Russell B., Associate Professor of Civil Engineering, Univ. of So. Car., Columbia, S. C. C. R. McMillen, R. L. Sumwalt.

McFarland, Dalton E., Instructor in Engineering Administration, Mich. College M. & T., Houghton, Mich. S. R. Price, E. J. Townsend.

Means, R. E., Professor of Architecture and Civil Eng., Okla. A. & M. College, Stillwater, Okla. E. R. Stapley, R. L. Flanders.

Miller, Charles M., Professor of Engineering, University of Wichita, Wichita, Kansas. L. E. Conrad, R. F. Morse.

Mobley, Gordon S., Assistant Professor of Civil Engineering, Univ. of Florida, Gainesville, Fla. C. D. Allen, F. H. Pumphrey.

Monk, Clarence B. Instructor in T. & A. M., University of Illinois, Urbana, Ill. W. M. Lansford, W. L. Collins.

Owen, William S., Dean of Faculty, Professor Naval Arch., Webb Inst. of Naval Arch., New York City. L. J. Ballard, E. H. Young.

Powers, Dean A., Assistant Professor of Electrical Engineering, Univ. of Toledo, Toledo, Ohio. E. O. Scott, J. B. Brandberry.

Rice, Percival S., Assistant Professor of Civil Engineering, Tufts College, Medford, Mass. E. F. Littleton, W. E Farnham.

Schlemmer, Alfred E., Instructor in Mechanical Engineering, Okla. A. & M. College, Stillwater, Okla. R. R. Irwin, E. R Stapley.

Smith, Thomas N., Instructor, Mich. College M. & T., Houghton, Mich. S. R. Price, E. J. Townsend.

Snowden, James R., Assistant Instructor, T. & A. M., University of Illinois, Urbana, Ill. W. J. Worley, J. O. Draffin.

Spielman, Maurice, Instructor in Mechanical Engineering, Ill. Inst. of Tech., Chicago, Ill. R. A. Budenholzer, J. C. Peebles.

Steele, Robert R., Instructor in Engineering Drawing, Tufts College, Medford, Mass. E. F. Littleton, W. E. Farnham.

Steen, G. Perry, Associate Professor of Civil Engineering, Univ. of N. M., Albuquerque, N. M. M. C. May, Roy Taft.

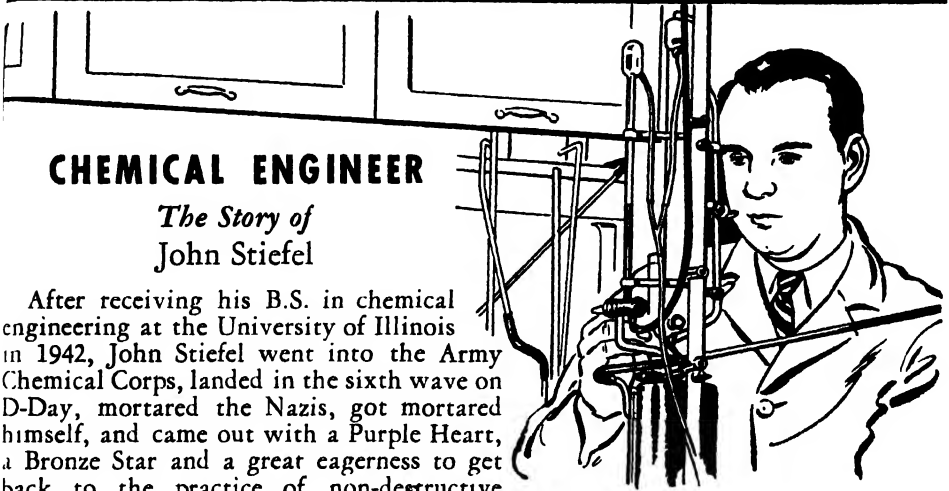
Thomas, John H., Assistant Professor of Mechanical Engineering, Univ. of Okla., Norman, Okla. F. S. Roop, R. V. James.

Tuma, Gerald, Assistant Professor of Electrical Engineering, Univ. of Okla., Norman, Okla. F. S. Roop, E. F. Dawson.

Turkington, Donald B., Assistant Professor of Mechanical Engineering, Univ. of Okla., Norman, Okla. F. S. Roop, R. V. James.

Wise, Edwin M., Manager, Apparatus Dept., General Electric Co., Houston, Texas. J. M. Waters, L. B Ryon.

Campus to GENERAL ELECTRIC



CHEMICAL ENGINEER

The Story of
John Stiefel

After receiving his B.S. in chemical engineering at the University of Illinois in 1942, John Stiefel went into the Army Chemical Corps, landed in the sixth wave on D-Day, mortared the Nazis, got mortared himself, and came out with a Purple Heart, a Bronze Star and a great eagerness to get back to the practice of non-destructive chemistry.

He spent three weeks travelling from one employment interview to another. In the end he decided on General Electric—particularly the Air Conditioning Department in Bloomfield, N. J.

"I figured," he says, "that a company like G.E., growing outside of purely electrical projects into such chemically based fields as atomics, paints, and plastics, would offer all the chemical opportunities I would want. I wasn't wrong."

At Bloomfield, John has helped staff the Works Laboratory and plan its expansion. He is now the laboratory's Chemical Section Head and a consultant on chemical engineering problems for the Department. With further expansion underway in personnel, equipment and floor space, John's job grows steadily.

For your copy of "Careers in the Electrical Industry," write to Dept. 237-6, General Electric Co., Schenectady, N. Y.

A chem engineering major at Illinois, John is now shaping up a chemical career in the G-E Air Conditioning Department

As commander of Company A of the 87th Chemical Mortar Battalion, John hit the beaches early on D-Day, won five battle stars

GENERAL ELECTRIC

Welding Trained Engineers Needed for Progress

INDUSTRIAL improvements and the way we learn to use them distinguishes our American society from the other and needy peoples of this earth. Our national production is largely accomplished through the use of steel . . . and arc welding, more than any other method, is making possible better and lower-cost fabrication. The steel-using world has yet much to gain through more widespread application of arc welding.

The Bechtel Corporation continues to construct welded pipelines of larger diameters and higher pressures, requiring higher-strength steel. Also, in fabricating vessels and their piping, we are always confronted with new and complex welding problems to make this equipment serve under higher pressures and increased temperatures, and resist corrosion.

In this work we need more and better trained men in the engineering field of welding. We look to the engineering colleges for young men with advanced training in welding engineering.

President
Bechtel Corporation
San Francisco, Calif

Bechtel Corporation has built many welded pipe lines, such as this 24-inch line.

Published through the courtesy of The Lincoln Electric Company, Cleveland 1, Ohio

56th Annual Meeting

American Society for Engineering Education

UNIVERSITY OF TEXAS

AUSTIN, TEXAS

June 14 - 18, 1948